KAHN SYSTEM STANDARDS

Trussed Concrete Steel Co.

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KAHN SYSTEM STANDARDS

A Hand Book OF Practical Calculation AND Application of Reinforced Concrete

COMPILED AND PUBLISHED

BY

ENGINEERING DEPARTMENT

TRUSSED CONCRETE STEEL COMPANY

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PREFACE

The rapid growth of Reinforced Concrete Construction makes necessary a Hand Book on Design, similar to those in use for the ordinary classes of building material.

The only data which has been available to the engineer or architect has been the scientific text book, in which the information presented is so involved as to be of little practical value to the busy designer. Otherwise he has had to resort to a series of empirical formulæ, or tables, which may only be justified by a few isolated tests.

The object of this Hand Book is to present to the designer tables and information in such form as to be immediately available for use in actual designs, and at the same time to have these tables founded on scientific formulæ approved by our very best engineering practice.

The data as presented is the result of a large amount of painstaking labor, and of most extensive experience in reinforced concrete, covering the design and construction of over a thousand structures, including buildings, bridges, tunnels, reservoirs, etc.

The work as presented deals mainly with the Kahn Trussed Bar.

The Kahn System of Reinforced Concrete, however, includes in its application two other types of reinforcement.

The Kahn Rib Metal consists of a series of straight bars or ribs connected laterally by light cross members rigidly attached to the ribs. The material is made in sheets, consisting of nine ribs, and is supplied in meshes from 2 to 8 inches, varying by inches.

This metal is manufactured of the highest grade medium steel.

The Cup-Bar is a specially rolled section with cross ribs scientifically designed so that the bar cannot slip in the concrete.

It has positive advantages over all other deformed bars in that the fibres of the steel are not distorted in the process of rolling. The Cup-Bar develops a greater strength than any other bar having the same net area, owing to the fact that in the process of manufacture it has been rolled, or worked, in such a manner as to develop a more uniform and more compact fibre structure. This extra rolling increases the elastic limit and ultimate strength of the bar considerably but does not in the least affect its ductility. It is manufactured in sizes from 3/8 to 1 1/4 inches, varying by 1/8 of an inch, the area of the bar being equivalent to the square bar of the same designation.

The Trussed Concrete Steel Co. publishes special literature descriptive of these two products, which will be gladly furnished to those interested.

All of these three types of reinforcement are carried constantly in stock at our various shops, ready for immediate shipment.

TRUSSED CONCRETE STEEL CO., Detroit, Mich.
TRUSSED CONCRETE STEEL CO., LTD., London, Eng.
TRUSSED CONCRETE STEEL CO., OF CANADA, LTD.,
Toronto, Can.

REINFORCED CONCRETE

What It Is

When, in the late 60's, Monier, a French gardener, began making flower pots, boxes and small water tanks out of concrete and imbedded wire in the material to increase its strength and decrease its weight and bulk, he little thought that forty years later the principle which he used and upon which he was granted a patent, would be used throughout the entire world in the erection of millions upon millions of dollars worth of construction work. There has been no class of structures, no line of the building trades which has not been affected by reinforced concrete, and many of them have been revolutionized. The story of the development and growth of the use of this form of construction has filled volumes, while here it can only be touched upon briefly.

HOW FIRST USED

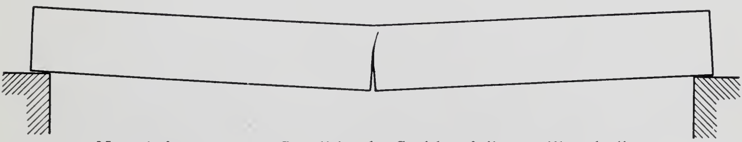
Concrete is a rock-like substance formed by the mixture of cement, sand, stone and water. It is the result of the cementing together, through chemical action between the cement and water, of various sizes of stone so proportioned with the other material that all voids within the resulting mass are filled.

CONCRETE DEFINED

Reinforced concrete is exactly what the name implies. It is concrete in which steel has been imbedded to give additional strength and elasticity.

REIN-FORCED CONCRETE DEFINED

Plain concrete when used in the form of pillars and posts, is capable of carrying heavy direct loads through its great compressive strength. But when it is subjected to a direct pull, that is, to tensile strains, it is weak.



No reinforcement. Small load—Sudden failure—like chalk.

For example, if a plain concrete beam is subjected to a load it will break apart at the bottom just as a piece of chalk would under

like conditions, being unable to resist the tension in the lower portion of the beam. In order to overcome this, reinforcing steel is used to give proper tensile strength and elasticity. The concrete in the top of the beam takes care of the compression. A properly reinforced concrete beam has, therefore, the strength of stone in resisting compression united with the tension resisting power of steel.

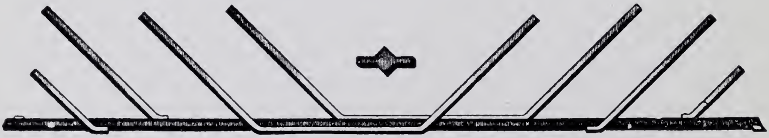
When a beam is loaded and supported at the two ends, it will have a tendency to deflect. To illustrate, assume that a beam is made up of a series of flat plates, or, in other words, like a pad of paper or a book, the difference being that in the pad of paper the leaves are not in any way connected to each other, whereas in a beam the adhesion of the various particles of the material ties the imaginary plates together. Now, when the supposed beam starts to deflect, one of two things will happen. Either the various plates separate, as when a book or pad of paper is bent, and in separating slide by one another; or, if the plates are held together and sliding is prevented, the particles in the upper plates compress and in the lower plates elongate.

It is thus seen that in addition to the compression and tensile stresses in the top and bottom of the beam, there are internal stresses of equal importance against which the concrete must also be properly reinforced. To accomplish this it is absolutely necessary that there shall be diagonal steel reinforcement extending well up into the mass of the concrete. This latter reinforcement *must be rigidly attached to the steel in the bottom of the beam* in order that all the steel may act together with the concrete in forming a properly reinforced beam. The Kahn Trussed Bar with its rigidly attached diagonals is, therefore, the ideal reinforcement.

THE KAHN TRUSSED BAR

KAHN BAR DESCRIBED

The Kahn Trussed Bar is made of a special grade of medium open-hearth steel with an elastic limit up to 42,000 pounds and an ultimate tensile strength of 70,000 pounds. The cross section is diamond shaped with two horizontal flanges or wings, projecting at diametrically opposite corners. These wing portions are sheared up at intervals and bent so as to make an angle of 45 degrees with the main portion of the bar. When the Kahn Trussed Bar leaves the factory, it looks like the following:



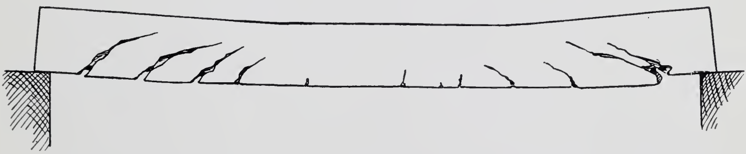
Kahn Trussed Bar—with alternating diagonals.

GENERAL HISTORY OF THE METHOD OF REINFORCING CONCRETE

A brief review of the general types of reinforcement used in the past, will make clear why they have been either abandoned or revised and why the Kahn Trussed Bar is now considered the *perfect reinforcement*, incorporating all the advantages of the old forms with the more modern improvements and refinements.

HORIZONTAL ONLY

It was originally thought that merely imbedding steel bars in the bottom of a concrete beam to take the tension was sufficient. This is true in some rare instances. While enough steel may be placed in the bottom of a beam, which, if pulled in a testing machine, could resist the desired amount of tension, it must be remembered that it is necessary to get the stress into the steel from the concrete, and there must be some positive means of doing this. The old idea was to depend upon adhesion. This was soon found to be inadequate and unreliable, as the plain bars would slip.

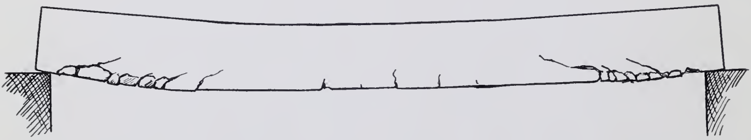


Horizontal reinforcement only. Method of failure when tested to destruction. Light load. Sudden failure caused by ends of reinforcement slipping and horizontal shear diagonal cracks in concrete.

In order to overcome this difficulty deformed bars of various types, such as twisted bars and bars with corrugations and lugs, were used to increase the friction between the steel and the concrete. When such bars were laid in the bottom of a concrete beam they did not slip in the concrete but the concrete would shear along a plane immediately above the bar. For this reason the strength of the bar could not be developed, and the beam was practically no stronger than if reinforced with plain bars.

LOOSE STIRRUP

Numerous tests were made on the older form of horizontal reinforcement and it was universally observed that when a beam was tested to destruction, it failed by the breaking of the concrete along lines beginning at the reinforcement at the ends and extending diagonally upwards towards the center of the beam. The cause was not known, but it was assumed that there were stresses in the concrete, and therefore loose vertical stirrups were placed in the

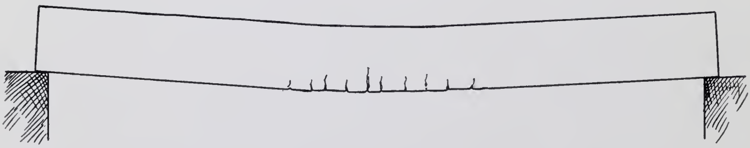


Horizontal reinforcement and loose stirrups. Method of failure when tested to destruction. Medium load. Sudden failure due to slipping of horizontal rods Shear of concrete on horizontal plane above bars but no diagonal cracks.

mass of the beam to resist these stresses. When beams were tested to destruction it was found that the main bar slipped and that the beam failed by shearing along a horizontal plane connecting the steel with the concrete.

RIGIDLY CONNECTED WEB MEMBERS

It was thus demonstrated that a positive connection must be made between the main steel bar and the members taking the web stresses. This led to the invention of the Kahn Trussed Bar. In this patented bar the members in the vertical plane, being made from a part of the main tension member, transmit stress from the body of the beam directly to the main steel bar. This is the ideal reinforcement. When beams, which have been reinforced with the Kahn Trussed Bar, are tested to destruction they fail by pulling the steel in two at the center, showing that there is



Kahn reinforcement. Method of failure when tested to destruction. Maximum load. Very gradual and ideal failure. Steel stretching in center.

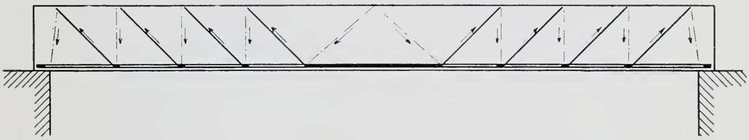
absolutely no unknown weakness in the beam and that the full proportion of the strength of all the materials is developed. It is,

therefore, the only means of reinforcing concrete that makes it possible to obtain the full value of the materials used.

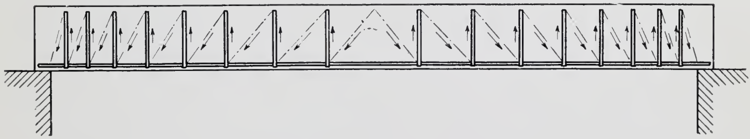
This feature is clearly shown by tests made by the French government, report of which was published in "Concrete and Constructional Engineering," of London. In these tests the beams, reinforced according to the Kahn System, carried 21 per cent. in excess of the beams reinforced with a series of stirrups and horizontal rods, which had hitherto been considered the best means of reinforcement. (The Trussed Concrete Steel Co. will be glad to supply a copy of this test in detail to anyone desiring same,)

INTERNAL STRESS ACTION

Note from the accompanying diagrams how, when a beam reinforced with the Kahn Trussed Bar, is loaded, the stresses in the beam are resisted either by an arch or a truss. In the arch each individual stress is resisted by a positive abutment in the form of a diagonal. In the truss the steel diagonals form the tension web members and the compression web members are supplied by the concrete. The advantageous feature in this is that the tension in the diagonals is brought into the main tension

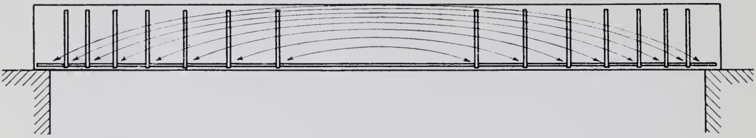


Truss action in beam reinforced with Kahn Trussed Bars. Note the action is that of a complete Pratt truss. No tendency to slip or slide.

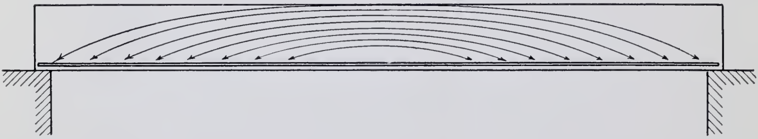


Truss action in beam with horizontal reinforcement and stirrups. Note the unbalanced horizontal component of the inclined stress and the tendency of the stirrups to slip along the horizontal reinforcement.

Arch action in beam reinforced with Kahn Trussed Bars. Note the perfect abutment for the inclined stresses. Perfectly rigid and no possibility of slipping.



Arch action in beam with horizontal reinforcement and stirrups. Note the unbalanced horizontal stress. Stirrups slip along the horizontal reinforcement, which, therefore, cannot be developed.



Beam with horizontal reinforcement only. Note arch action. Reinforcement furnishes no abutment for the inclined stresses, **and will slip.**

member directly because tension member and diagonals are one. The thrust of the arch or the pull of the web member of the truss is resisted by the diagonal and main bar combined. It is just as essential to have rigid attachment of the diagonal members in a concrete beam as it is to have strong, close fitting rivets between the lower chord and web plate of a steel plate girder.

CERTAINTY OF CALCULATION

That the calculated strength of a beam may be developed it is necessary that the materials be distributed in such a manner that the ultimate strength of each would be attained should the beam be tested to destruction. This anticipates the prevention of slipping of the reinforcing bars and the failure by tension in the concrete. The Kahn Trussed Bar cannot slip, and the concrete is reinforced against tension by the rigidly attached diagonals. It is clear, then, that beams reinforced with this bar will develop the ultimate strength of the materials, and since these values are known the materials can be so proportioned that each will be fully developed. In other words, the calculation of a beam reinforced with the Kahn Trussed Bar is absolutely certain and exact.

FIRE-PROOFNESS

It is a well-known fact that concrete, when subjected to intense heat, of 1500 degrees Fahrenheit or over, for a continuous period will loose a part of its water of crystallization. This condition will obtain for about one inch from the surface of the concrete in case of an extreme fire. Suppose the reinforcement is placed about one inch from the bottom of the beam. In case of a

very extreme fire, the lower inch of concrete will be practically ruined and its adhesion or immediate connection with a plain bar in the bottom of the beam will be completely destroyed. With the Kahn Bar, the large diagonals extend well up into the concrete beam and the effect of fire can almost be neglected, as the connection between the bar and its diagonals is still intact. (See Capt. Sewell's Report in Transactions of the Am. Soc. C. E.) This is perhaps one of the greatest features of the Kahn System of Reinforcement. A building erected on this plan is as good after a fire as before, while a building reinforced with plain bars is apt to be a complete ruin.

NOTES ON DESIGN IN GENERAL

The introduction of reinforced concrete into the field of building materials, has placed at the disposal of the designer and builder, a construction for which he has long been waiting. The material is plastic and monolithic and can be molded into any form to suit the highest imagination or ingenuity of the designer. It is no longer necessary to build with blocks and fixed units. Each particular structure is capable of an infinite variety of arrangements and combinations. The design then of a structure of maximum utility and economy requires the closest study and investigation.

DESIGN FOR UTILITY

The primary consideration in any design is that the finished structure shall serve the purpose for which it is built in the most adequate manner. This will determine to a large extent the location of the columns, the general framing and type of the floor construction, depth of girders, size of columns, etc. The design of a warehouse built to carry heavy loadings will vary, accordingly, from that of a residence. In the former, girders and beams placed close together might be used to advantage; in the latter, the appearance of unsightly beams in the ceiling of a room may be considered faulty design. Similarly in a factory the layout of the girders may be planned so as to accord with shafting for machinery.

A bridge is similar in this respect as its purpose, location and amount of waterway will predetermine to a large extent its design. The engineer or architect will find, however, that reinforced concrete, owing to its plasticity, lends itself admirably to every possible requirement and condition.

DESIGN FOR ECONOMY

Considering economy of design, the question immediately presents itself,—What system of reinforced concrete is most economical? It is here we set down the following dictum which we stand ready to prove at all times:—*The Kahn System of Reinforced Concrete per pound of stability of the finished structure is the most economical construction.*

ECONOMY OF THE KAHN BAR

The Kahn Trussed Bar with its rigidly attached diagonals is designed to resist every stress in the concrete except that of direct compression. There is no waste metal at any point and proper reinforcement is provided at every place it is needed. For instance, in the central portion of the beam where the full section of the metal is needed for bending moment and no reinforcement required for shear, the bar is unsheared and the full area of the metal is available. At the ends of the beam where the shear is a maximum and bending moment a minimum the flanges of the Kahn bar are struck up to form rigidly attached shear members.

ECONOMY OF INSTALLATION

Further than this, the Kahn Bar in reality consists of what may be considered a large number of separate members all rigidly attached and handled as a unit. The labor saving in handling a single piece as compared with many separate individual parts, is well known to any builder. (The Trussed Concrete Steel Co., publishes a booklet describing an actual experience proving this point. This booklet will be mailed on request.) Besides this the construction can be placed more accurately, as loose pieces are almost sure to be misplaced when the concrete is poured.

STRENGTH OF THE KAHN BAR

Strength of construction also requires that the diagonals be rigidly attached. These diagonals must transfer their shearing strains directly to the main tension member and when they are not attached this is impossible except through the adhesion of the concrete, a questionable quantity at best. (See Booklet on Tests made by the French Government, reprinted by the Trussed Concrete Steel Co.)

PRICES OF MATERIAL AFFECT ECONOMY

The system of construction being determined, there are many other considerations which affect the economy of a design. The location of the work and the relative prices of the different materials and various grades of labor are determining conditions. In one place, lumber and carpenter labor may be cheap, while the concrete materials may be expen-

sive. In such a location it would probably be economical to place girders close together. In other localities, the reverse conditions may be true and the opposite design would be the most satisfactory. In some localities, such as in the Middle West and East, hollow tile is relatively cheap and it would then be best to use reinforced hollow tile construction and not solid concrete slabs. All such conditions should have the closest study of the conscientious designer.

ENGINEERING DEPT. of TRUSSED CONCRETE STEEL CO.,

It is to take care of all such matters as these, to study each particular problem from every possible angle in order to get the best possible construction for each individual structure, that the Trussed Concrete Steel Co. has organized its large Engineering Department with branches in all the principal cities. In this Department are men of technical training and of wide experience in the engineering field, who are familiar with every type of construction and have specialized in reinforced concrete. This experience in reinforced concrete in all its applications places this department in a position to give expert advice on all such work. This advice together with preliminary plans and estimates is rendered gratis to all parties contemplating building. The information thus given may often mean a saving of thousands of dollars in the construction.

DETAIL PLANS FOR REINFORCED CONCRETE WORK

For any work in which it is decided that the Kahn System will be used, complete detailed drawings and specifications of the reinforced concrete construction are prepared. These drawings show clearly the exact location of each reinforcing bar and the detailed size of all the concrete work. Each bar when it leaves the factory is given a distinctive mark which corresponds with its marking on the drawing. Each bar is designed for a distinct place in the structure and the builder can tell at a glance where it belongs. The plans are prepared gratis for any structure in which the Kahn Trussed Bars are used. We co-operate to the fullest extent with all architects, engineers and contractors.

Further information, including literature showing the application of the Kahn System to all forms of construction can be obtained by addressing

Trussed Concrete Steel Co, Detroit, Mich.
Trussed Concrete Steel Co., Ltd., London, Eng.
Trussed Concrete Steel Co., of Canada, Ltd.
Toronto Can

SHEARING ON KAHN BARS

*

Standard Shear of Kahn Bar,
Middle Portion Left Unsheared.
Code word—Sacalais.

†

Center Shear of Kahn Bar.
Entire Bar Sheared to Center.
Code word—Sacafundo.

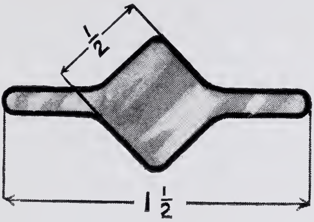
One Way Shear of Kahn Bar.
All Diagonals Sheared Inclining in one direction.
Code word—Sacafacido.

Special Shearing on Kahn Bars.
As directed by purchaser.

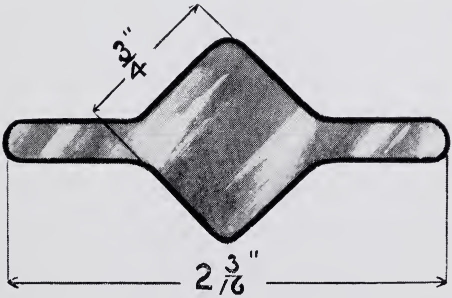
NOTE:—Sketch marked (*) shows shearing of bars with diagonals opposite. This type of shearing is provided on 6 in. and 8 in. diagonals.

Sketch marked (†) shows shearing of bars with diagonals alternating as provided with 12 in., 18 in., 24 in. and 30 in. diagonals.

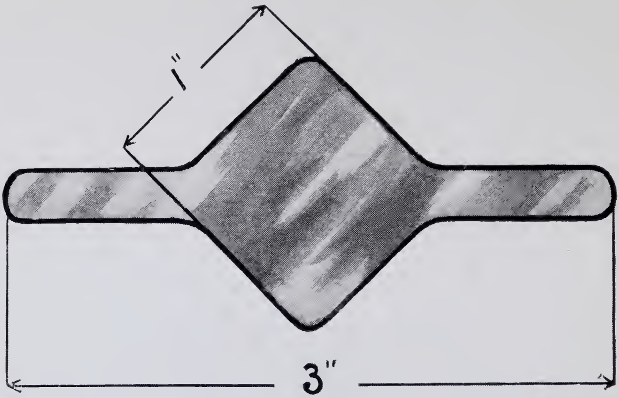
SECTIONS OF KAHN TRUSSED BAR



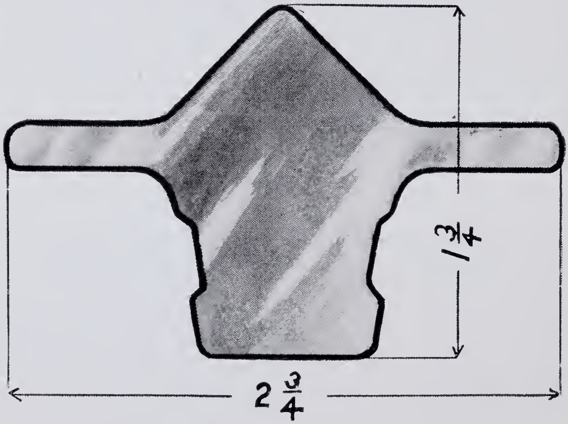
½″x1½″ Kahn Trussed Bar.
Weight—1.4 pounds per foot.
Area—0.41 square inches,
Standard length of Diagonals—6 inches.
Code word — Bandreich.



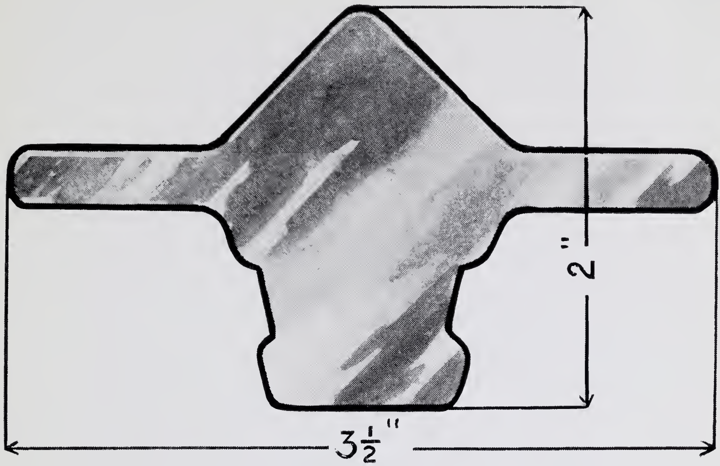
¾″x2 3/16″ Kahn Trussed Bar.
Weight—2.7 pounds per foot.
Area—0.79 square inches.
Standard length of Diagonals—12 inches.
Special lengths—8 inches and 18 inches.
Code word—Bandreifen.



1″x3″ Kahn Trussed Bar.
Weight—4.8 pounds per foot.
Area—1.41 square inches.
Standard length of Diagonals—24 inches.
Special lengths—18 inches and 30 inches.
Code word—Bandrjis.



1¾″x2¾″ Kahn Trussed Bars.
Weight—6.8 pounds per foot.
Area—2.00 square inches.
Standard length of Diagonals—24 inches.
Special lengths—18 inches and 30 inches.
Code word—Bangkraut.



2"x3½" Kahn Trussed Bar.
Weight—10.2 pounds per foot.
Area—3.00 square inches.
Standard length of Diagonals—30 inches.
Special lengths—24 inches.
Code word—Bangled.

CODE WORDS FOR LENGTH OF DIAGONALS

6-inch—Sacabrocas.
8 " —Sacabuxas.
12 " —Sacacorcho.
18 " —Sacadilla.
24 " —Sacadoria.
30 " —Saccadirst.

ALLOWABLE STRESSES, METHODS OF DESIGN, ETC.

MONOLITHIC ACTION

It is difficult in reinforced concrete work to adopt an arbitrary theory of design and fixed working stresses, which shall apply to structures of every class. To design correctly each particular problem should have individual attention and methods of design adopted accordingly. Concrete work being built monolithic should be treated accordingly and not analyzed into separate units as is done with ordinary materials where units are dealt with. The great additional strength of a monolithic construction of this kind is apparent. If any particular part of a floor is heavily loaded the floor adjacent will come to its assistance and will distribute the concentrated loading over a large area of floor space.

EFFECT OF VIBRATION

In the case of vibratory loadings such as caused by moving machinery, actual experiments have shown that concrete is less effected than any other building material. The Trussed Concrete Steel Co. have built many such structures and there is not the least tremor throughout the building when machinery is in operation.

STRENGTH DUE TO ARCH ACTION

Reinforced Concrete, when built continuously over a large floor area, has great additional strength due to interior arch action in the concrete. This arch action will in itself carry considerable load without causing any stress in the reinforcement. This of course is more marked in a floor where the depth is large compared with the span, than where the reverse is true. It would therefore seem proper to design a deep floor supported on all sides by similar construction with greater working stresses than a thin isolated panel built probably 20 feet in the air and unsupported by adjacent construction.

Other points to be considered in this connection are the quality of the materials and the grade of the workmanship.

The method of design, presented in this book, must be considered in the light of the above and may be varied to agree with any special conditions as the designer sees fit. The theory as presented is conservative and accords with good practise for work of this class. The additional strength due to monolithic construction, arch action, and tensile strength of concrete is entirely neglected in the calculations and thus an additional factor of safety is given to all work designed on this basis.

THEORY OF REINFORCED CONCRETE WORK

MOMENT OF RESISTANCE OF SIMPLE BEAM

The following theoretical analysis is based on the use of what is known as the "Straight Line" formula. This is a formula which is daily becoming more generally adopted and is embodied in the building requirements of almost all American cities and that of the Prussian government. It is recommended by the most authoritative text books, both foreign and native, and has the great advantage of simplicity and directness. It corresponds with the accepted theory of flexure as applied to other materials and is admittedly correct within allowable working stresses. If the theory errs at all, it errs on the side of safety.

This theory is based on the following assumptions:—

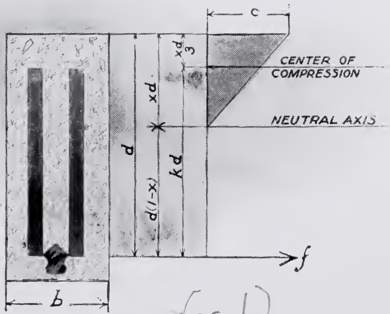
1st. A section plane before bending remains plane after bending; that is, the stress on any fibre is directly proportional to its distance from the neutral axis.

2nd. The tensile strength of the concrete is entirely neglected.

3rd. There are no initial strains in the beam.

4th. All shearing strain is provided against and there is no slipping between the concrete and the steel.

5th. The modulus of elasticity of concrete in compression is constant.



(xd)

Referring to figure:

d =distance from extreme compressed fibre to center of steel.
x d=distance from the extreme compressed fibre to the neutral axis.
x =ratio of depth of neutral axis to depth, (d) of steel.
k d=distance from center of compression of concrete to center of steel.
k =ratio of this distance to depth of beam (d). = a fraction
b =breadth of beam.

$m = \frac{E_s}{E_c} = \frac{\text{modulus of elasticity of steel.}}{\text{modulus of elasticity of concrete.}}$

A_s = area of steel reinforcement.

p = ratio of area of steel to area of concrete $= \frac{A_s}{bd.}$ $pbd = A$

c = compressive stress in extreme fibre of concrete.
f = tensile stress in steel.
RM = moment of resistance of beam.
RM = bending moment.

The total compression in the beam must equal the total tension. Equating these forces:

$\frac{1}{2}\, c\, b\, x\, d = p\, b\, d\, f = A_s f$ or

$$\tfrac{1}{2} c x = p f \qquad [1]$$

According to assumption 1st above

$$\frac{c}{f} = \frac{x}{m\ (1\text{-}x)} \qquad [2]$$

Combining equations [1] and [2]

$\frac{1}{2} x^2 = m\ (1-x)\ p$, whence

$$x = -pm + \sqrt{(pm)^2 + 2\ pm} \qquad [3]$$

Again combining [1] and [2]

$$p = \frac{1}{2} \frac{c^2 m}{f\ (f + cm)} \qquad [4]$$

The stress strain curve being a straight line, the center of compression is located $\frac{2}{3}\ x\ d$ above the neutral plane.

Taking moments about the neutral axis:

$$RM = \left[\frac{1}{3} c\, x^2 + p\, f\ (1\text{-}x) \right] bd^2 \qquad [5]$$

Taking moments about the center of the steel:

$$RM = \frac{c\, x\, bd^2}{2} \left(1 - \frac{x}{3} \right) = k\, \frac{c\ x\ bd^2}{2} \qquad [6]$$

Taking moments about the center of compression in the concrete.

$$RM = \left(1 - \frac{x}{3} \right) d\ A_s\ f = k\ d\ A_s\ f \qquad [7]$$

From equation [7] it is at once evident that the moment of resistance of a concrete beam is dependent only on the factor (k), the area of the reinforcement, the depth of the beam, and the allowable

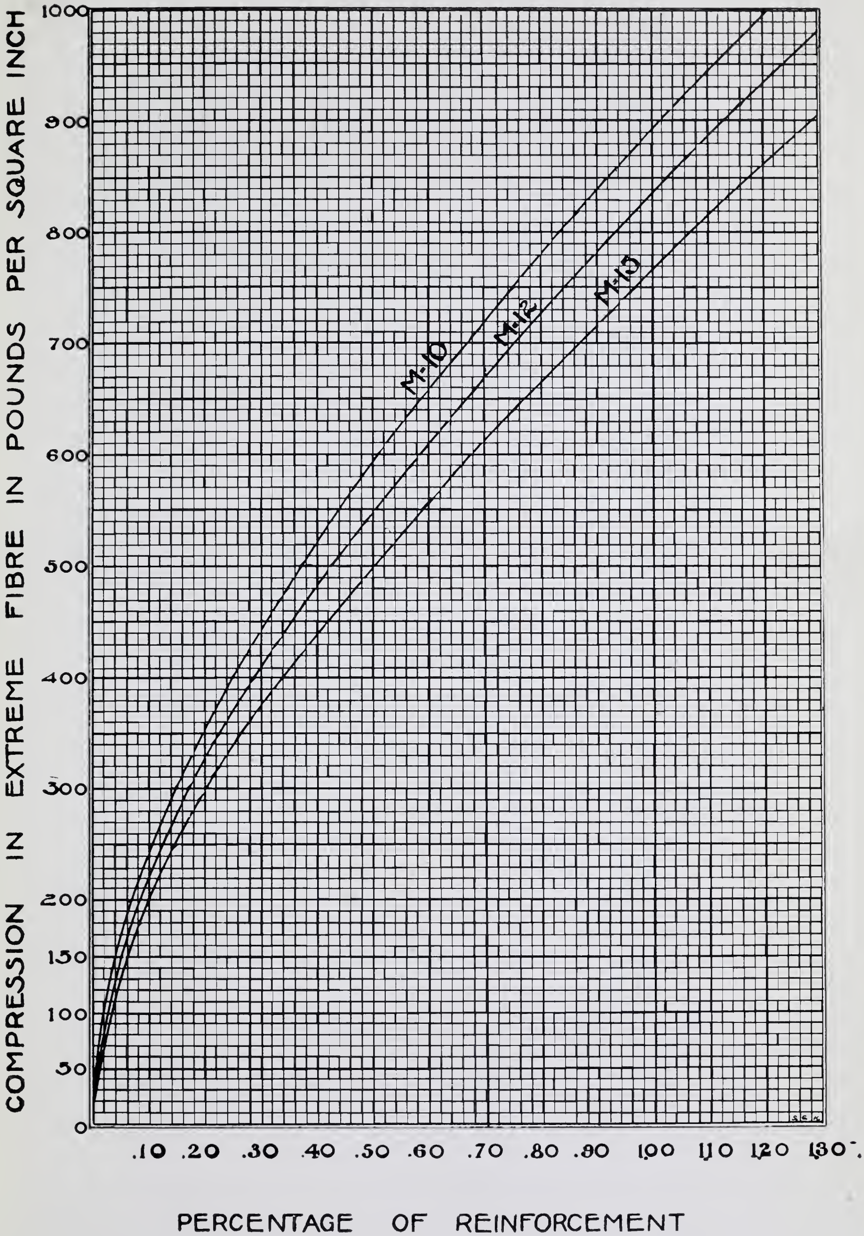

COMPRESSION IN EXTREME FIBRE IN POUNDS PER SQUARE INCH
1000
900
800
700
600
500
400
300
200
150
100
50
0
M-10
M-12
M-15
.10 .20 .30 .40 .50 .60 .70 .80 .90 1.00 1.10 1.20 1.30%
PERCENTAGE OF REINFORCEMENT

Fig. No. 2.

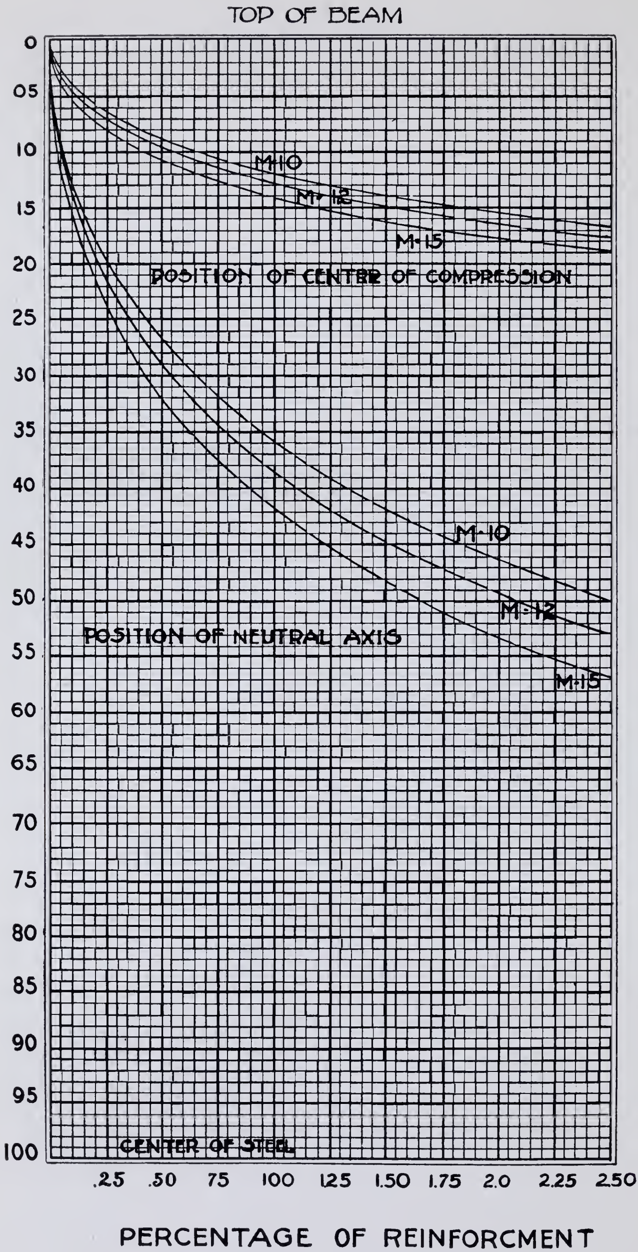

TOP OF BEAM
0
05
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
M-10
M-12
M-15
POSITION OF CENTER OF COMPRESSION
M-10
M-12
M-15
POSITION OF NEUTRAL AXIS
CENTER OF STEEL
.25
.50
75
100
125
1.50
1.75
2.0
2.25
2.50
PERCENTAGE OF REINFORCMENT

Fig. No. 3.

stress in the steel, with this important proviso,—*that the allowable compressive stress in the concrete is not exceeded.* This allowable stress will not be exceeded if the percentage of steel is kept below the value as determined by equation (4). It will be seen from equation (4) that if we assume a value for (f) equal to 16,000 pounds per sq. in. and also values for (m) that curves can be plotted showing the relation between the percentage of the metal and the compressive stress in the concrete.

In Figure 2 these curves are shown for values of (m) equal to 10, 12 and 15 and based on a stress in the steel equal to 16,000 pounds per sq. in.

From these tables it will be seen that if the percentage of steel does not exceed 1 per cent. for good rock concrete, there is no danger of the concrete failing by compression.

The factor (k) in equation (7) is the distance between the center of compression of the concrete and the center of the steel. It depends entirely for its value on the position of the neutral axis. From the equation (3) it is seen that the position of the neutral axis is dependent entirely on the percentage of the reinforcement and the values of (m).

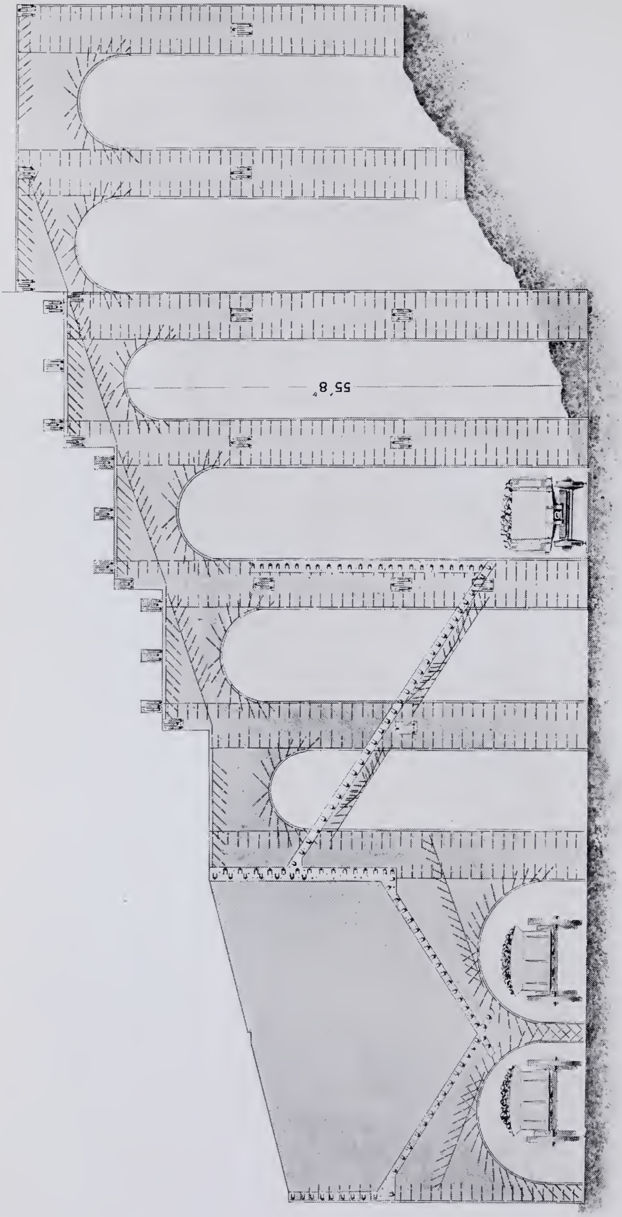
Again assuming (m) equal to 10, 12 and 15, in equation (3), curves as shown in figure 3 on page 24 are drawn showing the position of the neutral axis for various percentages of metal. From these curves the values of the factor (k) are readily obtained and are shown properly plotted in the same figure. An inspection of these curves will show at a glance that for all ordinary practical percentages of reinforcement, this factor (k) does not vary appreciably. It reduces to a value equal to .86 when the percentage of metal equals 1 per cent. For all lower percentages of metal its value is greater. It is, therefore, a very safe assumption to reduce our equation of (7) to the following simple formula:—

$$RM = .86\, d\, A_s\, f \qquad [8]$$

or for f=16,000 pounds per sq. in.

$$RM = 13{,}760\, d\, A_s \qquad [9]$$

For isolated beams, *the percentage of reinforcement must not exceed 1 per cent for good rock concrete.* This does not apply to beams with double reinforcement and T beams, which will be treated later.



Cross Section of Pine Hill Coal Breaker
Minersville, Pa.

DOUBLE REINFORCEMENT.

In the case of isolated beams when the percentage of tensile reinforcement exceeds 1 per cent., it is customary to provide compressive reinforcement to take care of this excess. The formulæ for design of beams with double reinforcement as ordinarily presented in text books are so complicated and involved as to be of little practical value. The following method of determining the amount of compressive reinforcement is simple, direct and accurate.

Assume an extreme fibre stress in the concrete of 750 pounds per sq. in. and a value of m equals 15. The stress in the fibre near the compressive reinforcement will be slightly less, say 720 pounds per sq. in. As (m) equals 15, the compressive stress in the steel is 10,800 pounds per sq. in. or slightly more than two-thirds of the allowable stress of steel in tension. In other words, the steel in tension is 50 per cent. more available than that in compression. That is if there is one square inch of reinforcement in excess of the allowable percentage in an isolated beam, there must be provided 1½ sq. in. of compressive reinforcement.

The neutral axis in the beam remains in the same location as in the simple beam, as the allowable unit stresses are the same and the location of the neutral axis is determined by equation (2.) The steel in compression being placed above the center of compression in the simple beam, the value of the factor k would tend to be increased so that equation 9 can be used with perfect safety in this case. To summarize:—

In the case of isolated beams, in which the percentage of tensile reinforcement exceeds 1 per cent. provide compressive reinforcement equal in area to $\frac{3}{2}$ of the excess area of tensile reinforcement. Then design by equation 9.

T BEAMS

When beams or girders are built so as to form part of a floor construction, the floor slab will act with and may be considered part of the same. In the construction of such a floor the concrete in the beam and slab must be placed continuously so that the two will be perfectly united.

In the design of such a T beam, there are four points which must be investigated and the design must satisfy each of these conditions. These four considerations govern the width of the floor slab that shall be considered as acting with the beam. It is assumed in this discussion, that sufficient steel has been provided in tension and that the beams are spaced sufficiently far apart so that the spacing of beams will not determine the width of slab available. With these assumptions the four points in the design each of which must be investigated and satisfied are: (See figure 4.)

1st. Shear along the plane *m n*.
2nd. Shear along the planes *m o* and *n p*.
3rd. Span of beam as affecting width of T.
4th. Weakness in compression.

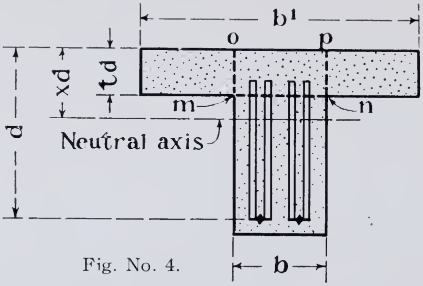


Fig. No. 4.

SHEAR ALONG PLANE *m n*

It is possible to make a complete analytic discussion of this matter, but the practical results of such analysis are alone interesting to the designer. Governed by this consideration, different authorities have given the width of slab available as acting with the beam, as from *3 to †10 times the width of beam. Good practice would limit this width to 5 times, i. e., b′ must not be greater than 5 b.

SHEAR ALONG PLANES *mo* **and** *np*

The shear along either of these planes is one-half that along *mn* and according to the above discussion, a width of slab, equal to twice the width of beam on either side of such beam, acts with the beam. Therefore, the floor slab to the extent of four times its depth on either side of the beam, may be considered as acting with the beam, i. e., b′ must not be greater than b+8 t d.

SPAN OF BEAM

The span of beam affects the width of slab available in that it takes a certain distance to distribute the stress to the outer edges of the T section. A width of slab not greater than 1-5 of the span of the beam may be considered as acting with the beam; i. e., b′ must not be greater than $\frac{1}{5}$ b.

WEAKNESS IN COMPRESSION

The width of flange *necessary* for compression is dependent on the area of the tensile reinforcement and the ratio of the thickness of the slab (t d) to the depth of beam (d.)

The table given on page 29 shows the width of flange necessary in the terms of the width of beam, for various percentages of reinforcement and ratios of slab depths. This table is based on the following theoretical analysis:

---

*Capt. John S. Sewell, Proceed. A. S. C. E. Dec., 1905.
†New York and Buffalo Building Laws.

RATIO OF WIDTH OF TABLE OF "T" REQUIRED TO WIDTH OF BEAM FOR VARYING PER CENTS OF STEEL AND DEPTHS OF SLAB.

Maximum Compression in Extreme Fibre = 750 Pounds per square inch.

Stress at Points Equidistant from Neutral Axis, same at all Points of Tee.

(t) Ratio of depth of Slab to depth of Steel	Percentage of Area of Steel, A, to Rectangular Area of Concrete, bd.											
	1¼	1½	1¾	2	2¼	2½	2¾	3	3 ¼	3½	3¾	4
.05	2.3	3.4	4.6									
.10	1.7	2.3	2.9	3.5	4.1							
15	1.5	1.9	2.4	2.8	3.2	3.7	4.1					
.20	1.4	1.8	2.1	2.5	2.8	3.2	3.5	3.8	4.2			
.25	1.4	1.7	2.0	2.3	2.6	2.9	3.2	3.5	3.8	4.1		
.30	1.3	1.6	1.9	2.2	2.4	2.7	3.0	3.3	3.6	3.8	4.1	
.35	1.3	1.6	1.8	2.1	2.4	2.6	2.9	3.2	3.4	3.7	3.9	4.2
.40	1.3	1.5	1.8	2.0	2.3	2.6	2.8	3.1	3.4	3.6	3.9	4.1
.413	1.3	1.5	1.8	2.0	2.3	2.6	2 8	3.1	3.4	3.6	3.9	4.1

NOTE:—For all ratios greater than .413, $\frac{b'}{b}$ has same value as given for .413.

NOTE:—Table gives values of $\frac{b'}{b}$

See figure 4.

Extreme fibre stress in concrete in compression $c = 750$ pounds per sq. in.

Tensile stress in steel $= 16{,}000$ pounds per sq. in.

$m = 15$,

From equation, page 22 $\frac{c}{f} = \frac{x}{m\,(1-x)}$

Solving, $x = .413$.

The stress at lower edge of slab $= \frac{x-t}{x}\,c$

Total compressive stress $=$

$$\frac{1}{2}\,c\,b\,x\,d + \frac{1}{2}\,(b'-b)\,\frac{(2\,x-t)}{x}\,ctd.$$

Total tensile stress $= 16{,}000\,p\,b\,d$,

Equating and solving for $\frac{b'}{b}$

$$\frac{b'}{b} = 1 + \frac{32{,}000\quad p-cx}{\frac{2x-t}{x}\,c\,t}$$

Substituting values of c and x above.

$$\frac{b'}{b} = 1 + \frac{32{,}000\ p-310}{(.826-t)\ 1816\ t,}$$

When the lower edge of the slab falls below the neutral axis, the analysis of the beam is the same as for a simple beam of width b′ and depth *d*.

An inspection of the table will show that under ordinary conditions of design, the slab will supply sufficient compressive reinforcement. In case it does not, steel must be provided in compression as indicated under design for "Double Reinforcement," page 27.

As the center of compression in the T beam will be relatively higher or equally as high as in the simple beam, the equation for moment of resistance for a simple beam may be used safely in the design of T beams, i. e.,

$$\mathbf{R\,M} = .86\ f\ A_s d = 13760\ A_s d.$$

To summarize, the design for T beams must satisfy each of the following conditions:

1st. b′ must not be greater than $5\,b$,
2nd. b′ " " " " " $8\,t\,d + b$,
3rd. b′ " " " " " $\frac{1}{5}$ of the span of beam,
4th. b′ " " " " " ½ the distance between the beams.

5th. Sufficient compressive area must be provided as shown in table.

6th. The tensile reinforcement may be proportioned by the formula **R M** = 13,760 $A_s d$.

The designer will readily see that shear plays an important part in beam design and that shear reinforcement must be provided. This shear reinforcement should be rigidly attached to the main tension member so that its stress may be transferred directly to this member. The Kahn Trussed Bar, with its rigidly attached diagonals, accomplishes this result in a simple, adequate and economical manner.

DESIGN OF BEAM LIMITED BY COMPRESSION IN CONCRETE

The theory of design for beams presented up to this point has been based on a safe working stress of 16,000 pounds per sq. in. in the steel in tension and an extreme fibre stress of 750 pounds per sq. in. in the concrete in compression. It has been shown that where the percentage of tensile reinforcement is less than 1 per cent. the compressive stress will be less than 750 pounds and therefore need not be considered.

In the previous discussion where more than 1 per cent. of reinforcement is required the extreme fibre stress is limited to 750 pounds, either by the use of compressive reinforcement or by making the beams T section.

On rare occasions, in the case of isolated beams and floor slabs, the percentage exceeds 1 per cent. and it is not found practical to use either of the two alternatives just mentioned. Under such circumstances the moment of resistance of the beam is limited by the extreme fibre stress (750 pounds) in the concrete, irrespective of the stress in the tensile reinforcement. The moment of resistance is then determined by equation *6* page 22, i. e.

$$\mathbf{R\,M} = \left(1 - \frac{x}{3}\right)\frac{cxbd^2}{2} = \left(1 - \frac{x}{3}\right)\frac{cx}{2}\;\frac{A_s\,d}{p}$$

The table given on page 32 gives the computed value of the moments of resistance and position of neutral axis for various percentages of reinforcement, based on this formula.

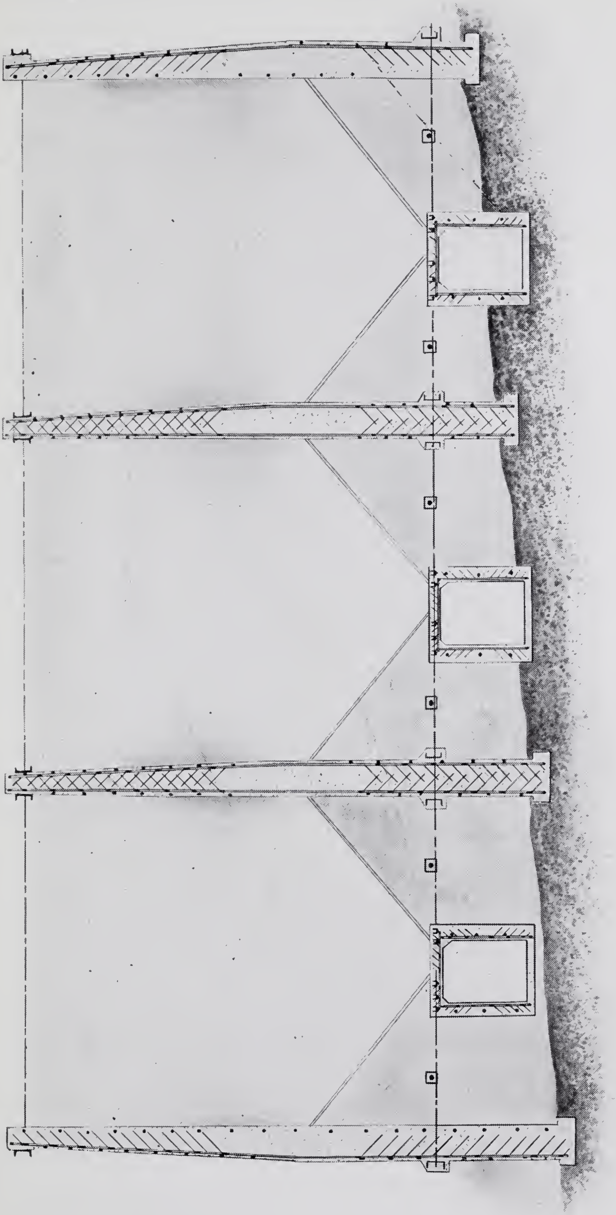
The designer should remember that it is usually decidedly uneconomical of material to design so as not to fully develop the strength of the steel reinforcement. Such a design should be avoided wherever possible.

Moments of Resistance of Beams, when the design is limited by the compression of the concrete and the full tensile strength of steel is not developed.

Percentage of Reinforcement	Position of Neutral Axis Values of X.	R M Depending on Area of Steel	R M Depending on Area of Concrete
1.1%	0.4327	12620 dAs	139 bd^2
1.2%	0.4464	11880 dAs	142 bd^2
1.3%	0.4592	11220 dAs	146 bd^2
1.4%	0.4712	10640 dAs	149 bd^2
1.5%	0.4825	10120 dAs	152 bd^2
1.6%	0.4932	9660 dAs	155 bd^2
1.7%	0.5033	9240 dAs	157 bd^2
1.8%	0.5129	8860 dAs	159 bd^2
1.9%	0.5220	8510 dAs	162 bd^2
2.0%	0.5307	8190 dAs	164 bd^2
2.1%	0.5389	7890 dAs	166 bd^2
2.2%	0.5468	7620 dAs	168 bd^2
2.3%	0.5545	7370 dAs	170 bd^2
2.4%	0.5617	7130 dAs	171 bd^2
2.5%	0.5687	6910 dAs	173 bd^2
2.6%	0.5755	6710 dAs	174 bd^2
2.7%	0.5819	6510 dAs	176 bd^2
2.8%	0.5882	6330 dAs	177 bd^2
2.9%	0.5942	6160 dAs	179 bd^2
3.0%	0.6000	6000 dAs	180 bd^2

Where percentage is 1% or less

$R\,M = 13760\ d\ A_s$



Cross Section Cement Storage Bins for Northwestern States Portland Cement Co., Mason City.
Cowham Engineer Co., Engineers.

SHEAR IN REINFORCED CONCRETE BEAMS

The vertical shear at any section of a beam is the reaction at one end minus that part of the load lying between the end and the section. It is shown in mechanics that at any point in a beam the vertical unit shear is equal to the horizontal unit shear.

The distribution of the shearing stresses on the vertical section of a beam of homogeneous material is shown in figure No. 5. It will

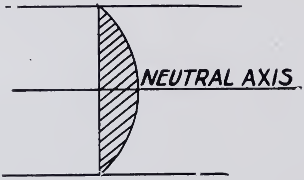


Fig. No. 5.

be noted that the shear varies as the ordinates to a parabola with the maximum shear at the neutral axis and equal in magnitude to $\frac{3}{2}$ the mean unit shear.

The distribution of shearing stresses on a vertical section of a reinforced concrete beam is shown by figure No. 6. The shear

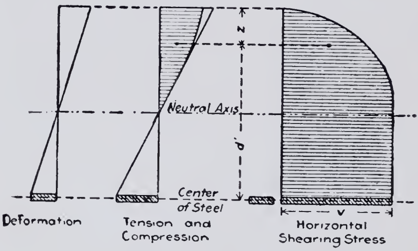


Fig. No. 6.—Distribution of Horizontal and Vertical Shear.

distribution in the beam of homogeneous material is similar to that of the reinforced concrete beam except for that portion of the curve below the neutral axis. As no tension is considered as acting in the concrete there will be no change in the intensity of the horizontal and vertical shearing stresses below the neutral axis, whereas in the beam of homogeneous material the intensities vary as shown by the figure. No. 5

In the flexure of a simple beam the upper fibres are compressed and the lower fibres are stretched in amounts proportionate to the distance of these fibres from the neutral axis.

From the above it is evident that at every point of a beam there exists a horizontal and vertical shear and also a longitudinal tension or compression.

By combining the bending moment stresses with the shearing stresses at the various points in a beam lines of so-called principal stress are drawn as shown in figure No. 7. At the center of the

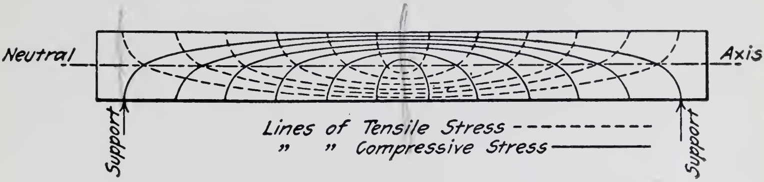


Fig. No. 7.—Lines of Stress in a Beam Under Flexure.

span the tensile and compressive stresses are horizontal; but as the ends are approached the lines of tensile stress incline upwards and those of compressive stress incline downwards so that at all points away from the center of the span these stresses have both horizontal and vertical components. The horizontal components reach a maximum at the center of the span and the vertical at the ends.

It will be noticed from the above figure that the lines of tension stresses incline up and away from the center at an average angle of 45 degrees, while the lines of compressive stresses cross these tension lines at right angles and incline down toward the ends of the span.

If the fundamental idea of reinforcing the concrete for tension is carried out, it is evident that steel members traversing the lines of principal tension stresses must be included in the design. If these members are to carry stresses they must be connected to some part of the structure that is capable of receiving it. The main tension member in the bottom of the beam provides such a connection, and it is only natural that this main tension member be utilized for this purpose. The web members in the Kahn System of Reinforcement are rigidly connected to the main bar so that there can be no slipping at the connection. These web members extend up into the compressed area of the concrete and the upper portion is gripped and held in place not only by the adhesion to the concrete, but also by the thrust in the concrete acting at right angles to the axis of the web member. A complete truss is thus formed with tension flange of steel, compression flange of concrete and steel tension diagonals rigidly held at either end.

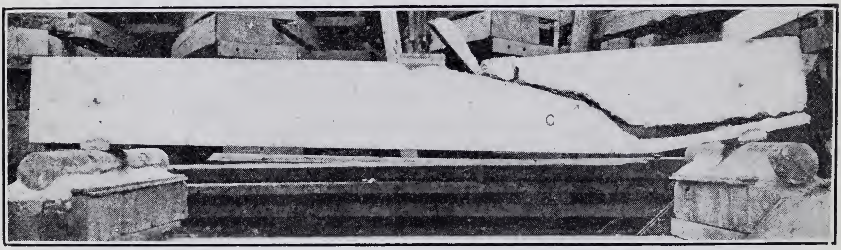
Merriman in his text book on mechanics gives an expression for maximum diagonal tension as $t = \frac{1}{2}s + \sqrt{\frac{1}{4}s^2 + v^2}$

Where "t" is the diagonal tensile unit-stress, "s" is the horizontal tensile unit-stress existing in the concrete, and "v" is

the horizontal or vertical shearing unit-stress. The direction of this maximum diagonal tension makes an angle with the horizontal equal to one-half the angle whose cotangent is $\frac{1}{2}\cdot\frac{s}{v}$.

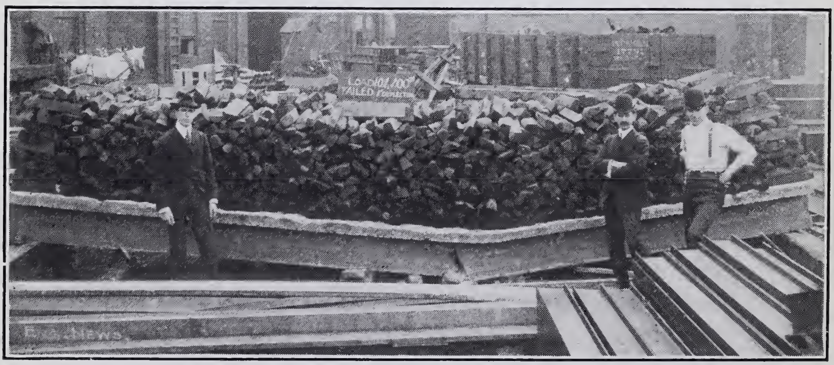
If there is no tension in the concrete, this reduces to $t=v$, and the maximum diagonal tension makes an angle of 45 degrees with the horizontal, and is equal in intensity to the vertical shearing stress.

When the diagonal tensile stresses developed become as great as the tensile strength of the concrete, the beam will fail by diagonal tension, provided there is no metallic web reinforcement. The accompanying cut gives the typical form which this failure takes. As the value of the maximum diagonal tensile stress developed in a beam is, by equation $(t=\frac{1}{2}s+\sqrt{\frac{1}{4}s^2+v^2})$, dependent upon the horizontal tensile stress developed at the same point, it is difficult to compute its actual amount. The best method seems to be to compute the horizontal and vertical shearing unit-stress, and make all comparisons on the basis of this value.



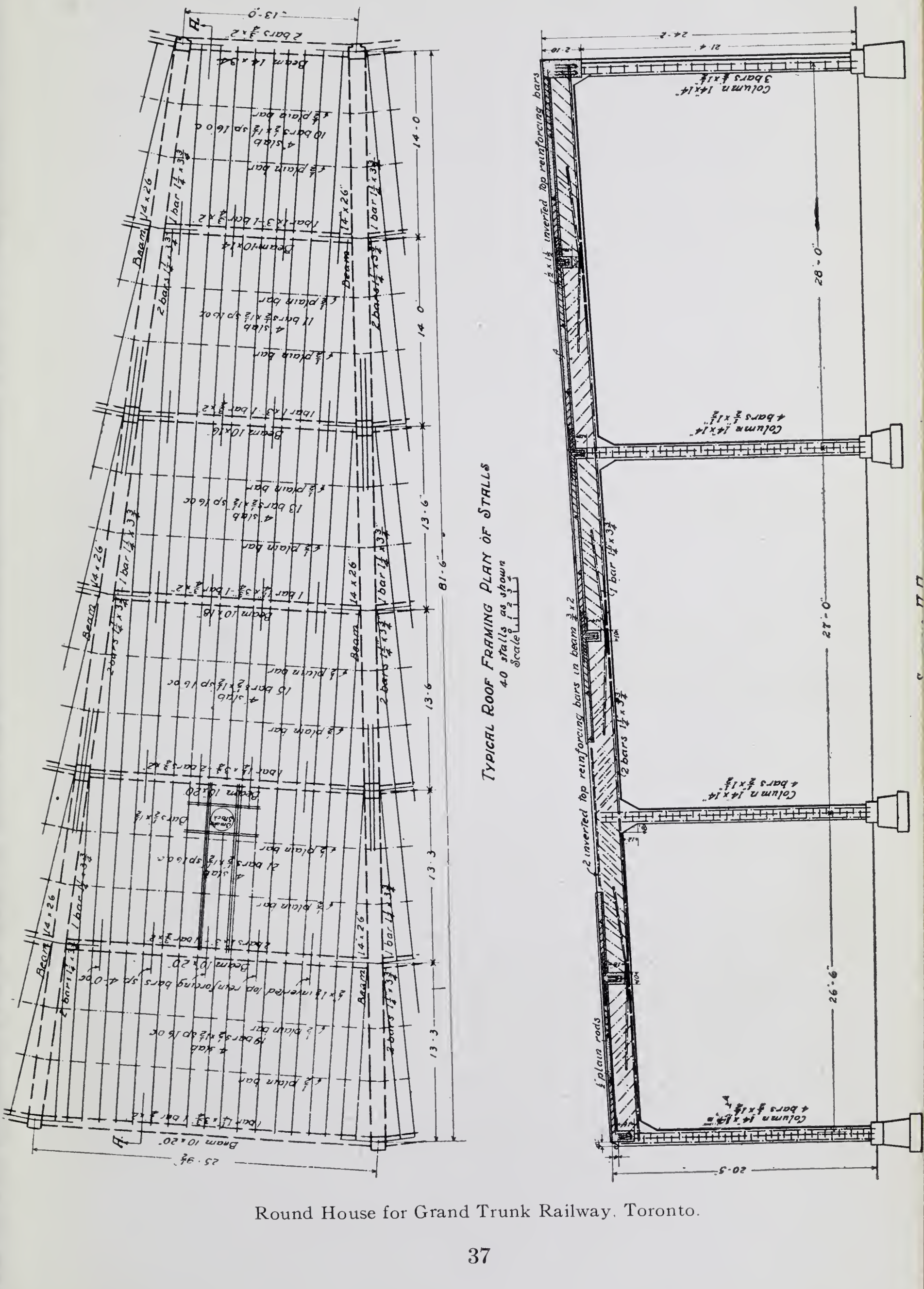
BESSEMER STEEL, HIGH CARBON, DEFORMED BAR

See Report of Boston Transit Commission, June 30, '04.
Fracture showing method of failure, due to shear, which occurs almost invariably when horizontal reinforcement is used. Steel stretched only to its elastic limit



BEAM REINFORCED WITH THE KAHN TRUSSED BAR

See Eng. News, vol. L, p. 349. See Eng. Record, vol. 48, p. 465.
Note that when tested to destruction the steel pulls in two.
Ultimate strength of steel developed.



Round House for Grand Trunk Railway, Toronto.

PIECES UNDER DIRECT COMPRESSION

Unhooped Columns

In combining steel and concrete to resist compression, theoretically the load is borne by the two materials in a ratio determined by their relative modulii of elasticity. With this ratio 1 to 15 and a safe stress in the concrete of 500 pounds the steel will carry 7500 pounds per square inch. The natural disposition of this reinforcing steel is near the periphery of the column. In this position the reinforcing steel will take up whatever secondary stresses may occur caused by the possible eccentric application of the applied loads or by unequaled settlement of the footings.

The longitudinal reinforcing rods should be stayed at intervals not exceeding fifteen times the diameter of the rod, or the least dimension of the column. With twisted and plain bar columns this staying is done by horizontal bands extending around the column or by spirally-wound hooping.

The cut on page 65 shows the adaptability of the Kahn bar to column construction. The prongs are of such length that they reach diagonally across the column and tie in the main bar at intervals of 6″ to 12″.

Columns loaded unsymmetrically and especially corner columns should be figured with lower unit stresses. On account of the monolithic nature of construction it is somewhat difficult to say just what eccentricity a certain loading gives. In outside columns there is, undoubtedly, an eccentric load, and this should be provided for in the design by allowing a lower fiber stress.

Hooped Columns

Hooped columns as developed by M. Considere consist of a number of longitudinal bars arranged on the circumference of a circle with a steel band wrapped around these bars in spiral turns varying from 1½″ to 4″ apart, depending upon the design. This form of reinforcement increases the compressive strength of the concrete greatly and enables it to withstand much greater deformation and unit stresses. Considere shows that plain concrete under compressive stresses tends to fail by splitting longitudinally and bulging laterally. By enclosing it in a spiral wrapping of sufficiently small pitch the lateral bulging is resisted and the con-

crete will not only stand higher stresses without failure, but will also undergo much greater shortening. For a theoretical discussion of this subject the reader is referred to "Experimental Researches on Reinforced Concrete," by Armand Considere, published by the McGraw Publishing Co. under date of 1906.

The table on page 64 is based upon the theory as developed by Considere. This theory is outlined by the following formula:

$P = A_c\ F_c = m\ (A_s + 2.4A_s^1)\ x\ F_c.$

Where P=safe load on column.

F_c=load per sq. in. on net section of core,

A_c=net area of concrete inside of hooping.

$$m = \frac{\text{modules of elasticity of steel.}}{\text{modules of elasticity of concrete.}}$$

A_s=Total area of cross section of vertical rods.

A_s^1=area of cross section of imaginary vertical rods having same quantity of steel as the hooping.

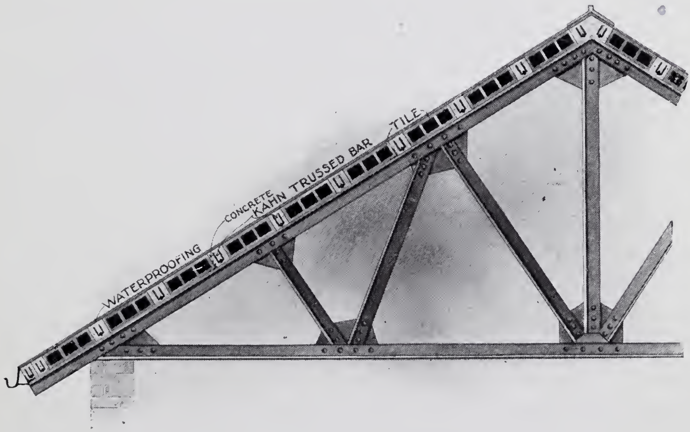
The following values were used in figuring the tables.

F_s=750 lbs.

m=15,

A_s=approximately $1\frac{1}{2}$ per cent. of cross section of core.

A_s^1=approximately $2\frac{1}{2}$ per cent. of cross section of core.



Typical Roof Construction Showing Application of Reinforced Concrete and Hollow Tile Design on Steel Trusses.

BENDING MOMENTS

Reinforced concrete differs from the ordinary types of building construction in that it is built continuous and monolithic. For this reason, girders and slabs must be designed to a large extent as continuous structures and provision must be made to take care of the negative bending moments occuring at the supports. This is done in practise by inverting Kahn bars in the top of the concrete over the support.

It will often be found that in order to make the construction perfectly continuous in accordance with the accepted theory of continuous beams, the negative bending moment over the support will exceed the positive bending moment at the center of the span. It has not been found practical, however, to design in this way. The reasons for this are:—

1st. The top bars cannot be laid with as great accuracy as the bottom bars.

2nd. The concrete cannot be placed as well.

3rd. Each span in a structure would not be independently stable, as it would depend for its stability upon the cantilever action of the adjacent span.

Sufficient top reinforcement, however, must be provided to thoroughly tie the construction together and to prevent the occurence of hair cracks due to slight deflection. The use of this top reinforcement reduces the bending moment at the center of the span.

The following scale of bending moments has been adopted by good practise in this country and abroad, is considered conservaative, and gives satisfactory results:—

B M = bending moment at center of span of the beam.

W = total uniform load on beam.

$$BM = \frac{1}{10} W l$$, l = span of beam.

For beams and slabs built in or continuous at both supports,

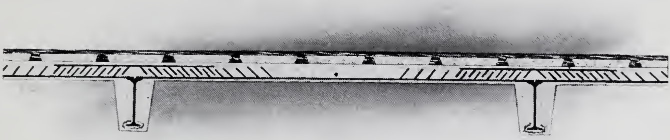
For beams and slabs built in or continuous at one support only

$$BM = \frac{1}{9} W l$$

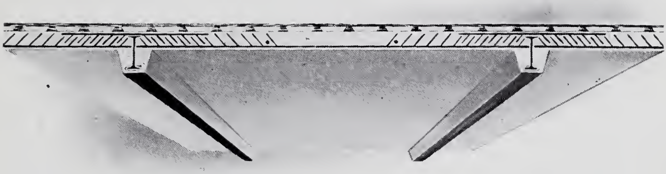
For beams and slabs freely supported,

$$BM = \frac{1}{8} W l$$

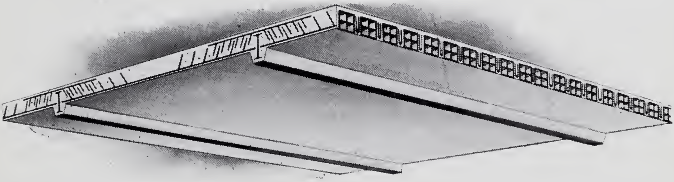
DETAILS OF FLOOR CONSTRUCTION FRAMING BETWEEN STEEL GIRDERS



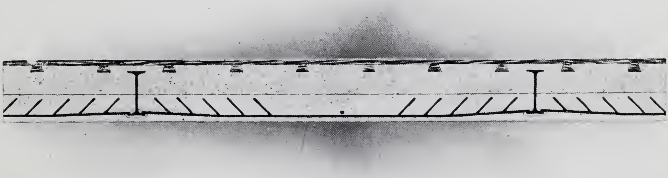
Reinforced Solid Slab Resting on Top of I Beams.



Solid Concrete Floor Slabs for Short or Long Spans.



Reinforced Hollow Tile Long Span Construction.



Slab Resting on Lower Flange of I Beam. Note flat Ceiling and Cinder Fill Over Concrete Construction.

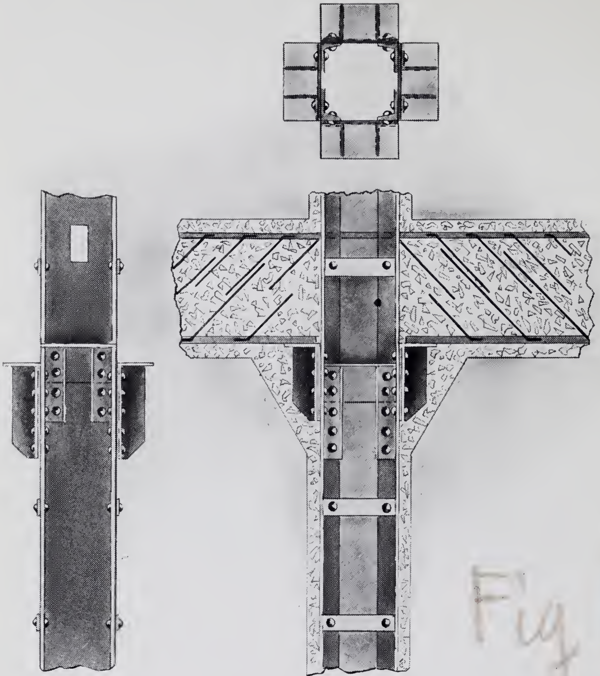
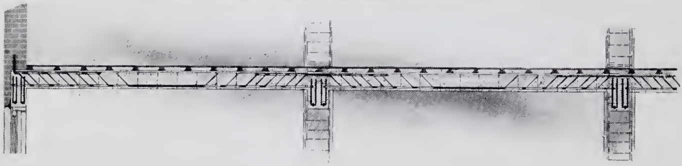
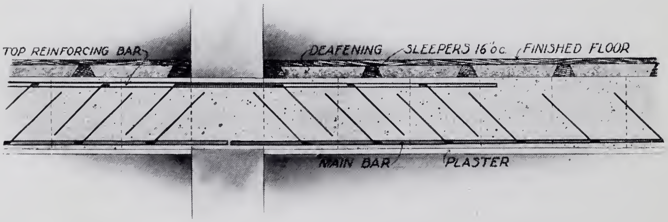


Fig K

Details of Connections for Concrete Girders Framing Into Steel Columns.



Typical Floor Slab Construction Framing Between Concrete Beams.



Note Continuous Action Over Supports Produced by Inverting
Kahn Bar in Top of Beam.

Fig K,

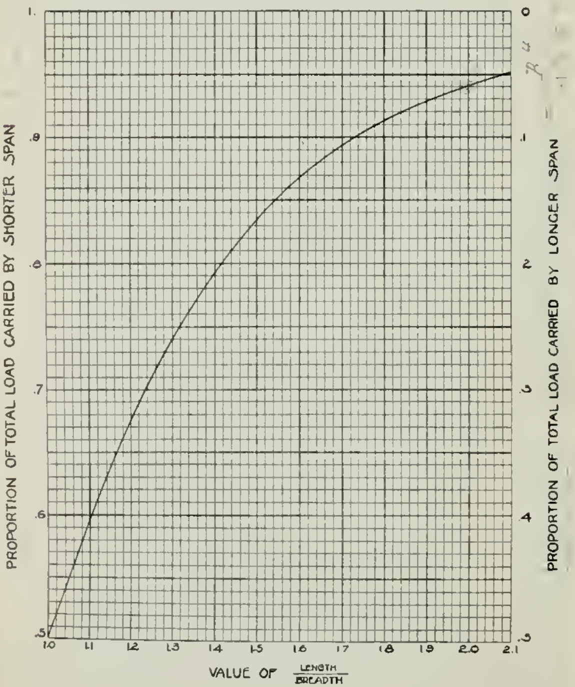
b6

RECTANGULAR FLOOR SLABS

When a slab is built in or freely supported at its four edges, the slab is reinforced in both directions,—

If A be the longer span of the panel and B the shorter, then the bending moments given above must be reduced by the factor $\frac{B^4}{A^4+B^4}$ for the longer span and by $\frac{A^4}{A^4+B^4}$ for the shorter span in order to obtain the actual bending moments. L^4 L^4

The greatest bending moment will always be that for the shorter span. The curve shown below will show the value of this factor for varying proportions of length and breadth of panel.



MAR - 4 1908

Last formula on Kahn p 40: $M = \frac{W}{8} L$;

where L = span.

In a plate, supported along its sides,

b = span; and $M = \frac{W}{8} b$. See sketch below.

According to Kahn p 43, in a plate supported or fixed at its 4 edges, the maximum moments, given on p 40, must be reduced by the factor (our symbols, p 493) $\frac{L^4}{L^4 + b^4}$; or, for a plate supported on its 4 sides,

$$M = \frac{W}{8} b \frac{L^4}{L^4 + b^4}$$

$$= \frac{W}{8} \frac{L^4 b}{L^4 + b^4};$$ as we have it.

EXPLANATION OF TABLES FOR SOLID CONCRETE FLOOR SLABS.

The tables for floor slabs given on pages 45 to 50 inclusive, are based on the theory of design as given in the preceding pages. They are computed as being built continuous over the supports and for a bending moment equal to $\frac{1}{10}$ W l^2. The loadings given are *safe live loads per sq. ft.* The full dead weight of the slab has been deducted in every case in preparing the tables. They can be used with safety in any slabs in which Kahn bars are used.

In order to produce proper continuous action, top reinforcing bars must be provided over the supports equal in area to one-fourth of the area of the bars in the floor. These bars should have a length equal to $\frac{4}{10}$ of the span of the floor.

In case the slabs are not built continuous but are freely supported, these tables can be used, but from the safe live loads given must be deducted.

$$\frac{\text{Safe live load}+\text{dead weight of slab per sq. ft.}}{5}$$

in order to find the safe live loading on the slab.

Floor slabs should have a thickness equal to at least one-thirtieth of the clear span.

EXPLANATION OF TABLES FOR REINFORCED HOLLOW TILE CONSTRUCTION

These tables, pages 53-56, are prepared on exactly the same basis as regards bending moments, loadings and use, as the tables for solid concrete floor slabs. This construction consists of a series of hard burned hollow tiles, laid with a space between. In this space is placed a Kahn bar and a rich mixture of concrete. In this way are obtained reinforced concrete joists separated by hollow tiles. These joists carry all the load while the tile serves merely as a filler to produce lightness.

In the case of the floors reinforced with ½x1½″ bars the construction is covered with a 1″ coat of concrete, and the floor with ¾″x2 $\frac{3}{16}$″ bars with a 2″ coat. This is in order to provide sufficient compressive area. These thicknesses may be increased if conditions warrant it.

The tables given cover the general cases occurring in practice. The designer will readily see a varied number of other combinations of hollow tile and concrete joists which he can use as occasion demands and which can be readily computed from the general theory already given.

Floors should not have a thickness less than one-thirtieth of the clear span.

SPACING OF BARS IN INCHES FOR VARIOUS SAFE LIVE LOADS PER SQUARE FOOT

4″ Slab ½″ x 1½″ Kahn Trussed Bars, Area = 0.41 sq. in.

Load in Pounds	Span in Feet 6	7	8	9	10
50					18.7
75				18.3	14.9
100			19.4	15.3	12.4
125			16.6	13.1	10.6
150		18.9	14.4	11.4	
175		16.8	12.8	10.1	
200	20.5	15.1	11.5		
250	17.1	12.5			
300	14.6	10.7			
350	12.8	9.4			
400	11.4	8.3			

$$B.\ M. = \frac{w\ l^2}{10}$$

$R.\ M. = 0.86 \times 3.25 \times 0.41 \times 16000$

Maximum Spacing = 16″

Minimum Spacing = 12.6″

4½″ Slab ½″ x 1½″ Kahn Bars, Area = 0.41 sq. in.

Load in Pounds	Span in Feet 6	7	8	9	10	11
50						16.8
75					16.4	13.6
100				17.0	13.7	11.3
125			18.5	14.6	11.8	9.8
150			16.2	12.8	10.4	8.6
175		18.9	14.4	11.4	9.2	
200		17.0	13.0	10.3	8.3	
250	19.4	14.2	10.9	8.6		
300	16.6	12.2	9.3			
350	14.5	10.7	8.2			
400	12.9	9.5				
500	10.6					

$$B.\ M. = \frac{w\ l^2}{10}$$

$R.\ M. = 0.86 \times 3.75 \times 0.41 \times 16000$

Maximum Spacing = 16″

Minimum Spacing = 10.9″

SPACING OF BARS IN INCHES FOR VARIOUS SAFE LIVE LOADS PER SQUARE FOOT

5″ Slab ½″ x 1½″ Kahn Trussed Bars, Area 0.41 Sq. in.

Load in Pounds	SPAN IN FEET						
	6	7	8	9	10	11	12
50						18.0	15.1
75					17.7	14.6	12.3
100				18.5	15.0	12.4	10.4
125				16.0	13.0	10.7	9.0
150			17.8	14.1	11.4	9.4	
175		20.8	15.9	12.6	10.2	8.4	
200		18.8	14.4	11.4	9.2		
250	21.5	15.8	12.1	9.6			
300	18.5	13.6	10.4	8.2			
350	16.2	11.9	9.1				
400	14.5	10.6	8.2				
500	11.9	8.7					
600	10.1	7.4					

$B.\ M. = \frac{wl^2}{10}$

$R.\ M. = 0.86 \times 4.25 \times 0.41 \times 16000$

Maximum Spacing 16″

Minimum Spacing 9.7″

6″ Slab ½″ x 1½″ Kahn Bars, Area 0.41 Sq. in.

Load in Pounds	SPAN IN FEET							
	8	9	10	11	12	13	14	15
50					16.8	14.4	12.4	10.8
75				16.7	14.0	11.9	10.3	8.9
100			17.2	14.2	11.9	10.2	8.8	7.6
125		18.6	15.1	12.5	10.4	8.9	7.7	
150		16.5	13.4	11.0	9.3	7.9		
175	18.7	14.8	12.0	9.9	8.3	7.2		
200	17.0	13.4	10.9	9.0	7.6			
250	14.4	11.4	9.2	7.6				
300	12.5	9.8	8.0					
350	10.9	8.7	7.0					
400	9.8	7.7						
500	8.1	6.4						

$B.\ M. = \frac{wl^2}{10}$

$R.\ M. = 0.86 \times 5.25 \times 0.41 \times 16000$

Maximum Spacing 16″

Minimum Spacing 7.8″

SPACING OF BARS IN INCHES FOR VARIOUS SAFE LIVE LOADS PER SQUARE FOOT

7″ Slab ¾″ x 2$\frac{3}{16}$″ Kahn Trussed Bars. Area = 0.79 Sq. in.

Load in Pounds	SPAN IN FEET									
	8	9	10	11	12	13	14	15	16	17
50										16.8
75									16.0	14.2
100							18.1	15.8	13.9	12.2
125						18.4	15.9	13.9	12.2	
150						16.5	14.2	12.4		
175					17.5	14.8	12.9			
200				19.0	15.9	13.6	11.7			
250			19.5	16.1	13.6	11.6				
300			17.0	14.0	11.8					
350		18.6	15.0	12.4						
400		16.6	13.5	11.1						
500	17.4	13.8	11.2							
600	14.9	11.8								
800	11.5									

$$B.\ M. = \frac{wl^2}{10}$$

$$R.\ M. = 0.86 \times 6 \times 0.79 \times 16000$$

Maximum Spacing = 16″

Minimum Spacing = 13.2″

SPACING OF BARS IN INCHES FOR VARIOUS SAFE LIVE LOADS PER SQUARE FOOT

8″ Slab ¾″ x $2\frac{3}{16}$″ Kahn Trussed Bars. Area = 0.79 sq. in.

Load in Pounds	SPAN IN FEET 6	7	8	9	10	11	12	13	14
250						18.2	15.3	13.0	11.2
300					19.2	15.9	13.4	11.4	9.8
350					17.1	14.1	11.9	10.1	
400				19.0	15.3	12.7	10.6		
500			19.9	15.8	12.8	10.6			
600			17.1	13.5	10.9				
800		17.3	13.3	10.5					
1000		14.2	10.9						
1200	16.3	12.0	9.2						
1400	14.1	10.4							

Load in Pounds	SPAN IN FEET 12	13	14	15	16	17	18	19	20
50						18.0	16.1	14.4	13.0
75					17.4	15.4	13.7	12.3	11.1
100				17.2	15.2	13.4	12.0	10.7	
125			17.6	15.3	13.4	11.9	10.6		
150		18.3	15.8	13.8	12.1	10.7			
175		16.6	14.3	12.5	11.0				
200	17.9	15.2	13.1	11.4	10.0				
250	15.3	13.0	11.2						

Maximum Spacing 16″ $\qquad B.M. = \frac{1}{10} wl^2$

Minimum Spacing 11.3″ $\qquad R.M. = 0.86 \times 7 \times 0.79 \times 16000$

SPACING OF BARS IN INCHES FOR VARIOUS SAFE LIVE LOADS PER SQUARE FOOT

10″ Slab ¾″ x $2\frac{3}{16}$″ Kahn Trussed Bars. Area = 0.79 sq. in.

Load in Pounds	SPAN IN FEET									
	6	7	8	9	10	11	12	13	14	15
125										17.7
150										16.1
175									16.9	14.8
200								18.1	15.6	13.6
250							18.4	15.6	13.5	11.8
300							16.2	13.8	11.9	10.4
350						17.2	14.4	12.3	10.6	9.3
400					18.8	15.5	13.1	11.1	9.6	8.4
500				19.5	15.8	13.0	10.9	9.3	8.1	
600				16.8	13.6	11.2	9.4	8.0		
800			16.6	13.1	10.6	8.8	7.4			
1000		17.8	13.7	10.8	8.7					
1200	20.6	15.1	11.6	9.2						
1400	17.9	13.1	10.1	7.9						

Load in Pounds	SPAN IN FEET									
	16	17	18	19	20	21	22	23	24	25
50			17.7	15.9	14.4	13.1	11.9	10.9	10.0	9.2
75		17.3	15.4	13.9	12.5	11.4	10.3	9.5	8.7	8.0
100	17.4	15.4	13.7	12.3	11.1	10.1	9.2	8.4		
125	15.6	13.8	12.3	11.1	10.0	9.1	8.2			
150	14.2	12.5	11.2	10.1	9.1	8.2				
175	13.0	11.4	10.2	9.2	8.3					
200	11.9	10.6	9.4	8.5						
250	10.3	9.1	8.2							
300	9.1	8.1								
350	8.1									

Maximum Spacing = 16″ $\qquad B.M. = \frac{1}{10} wl^2$

Minimum Spacing = 9″ $\qquad R.M. = 0.86 \times 9 \times 0.79 \times 16000$

SPACING OF BARS IN INCHES FOR VARIOUS SAFE LIVE LOADS PER SQUARE FOOT.

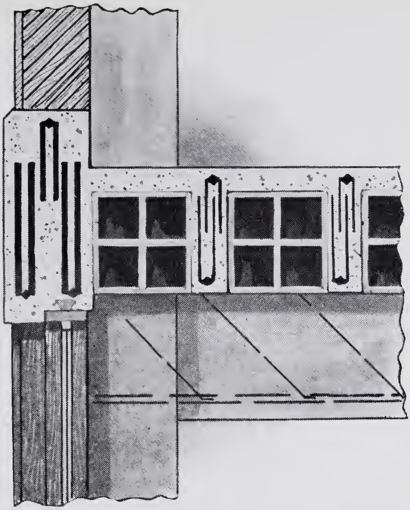
12″ Slab ¾″ x $2\frac{3}{16}$″ Kahn Trussed Bars. Area = 0.79 sq. in.

Load in Pounds	SPAN IN FEET										
	8	9	10	11	12	13	14	15	16	17	18
75											16.8
100										16.9	15.1
125									17.3	15.4	13.7
150									15.9	14.0	12.5
175								16.6	14.6	12.9	11.5
200							17.7	15.4	13.6	12.0	10.7
250						17.9	15.5	13.5	11.8	10.5	9.3
300						15.9	13.7	11.9	10.5	9.3	8.3
350					16.8	14.3	12.3	10.7	9 5	8.4	7.4
400				18.2	15.2	13.0	11.2	9.7	8.6	7.6	6.8
500			18.6	15.3	12.9	11.0	9.5	8.2	7.2	6.4	
600		19.8	16.0	13.2	11.1	9.5	8.2	7.1	6.3		
800		15.6	12.6	10.4	8.8	7.5	6.5	5.6			
1000	16.3	12.9	10.4	8.6	7.2	6.2					
1200	14.0	11.0	8.9	7.3	6.2						
1400	12.1	9.5	7.7	6.4							

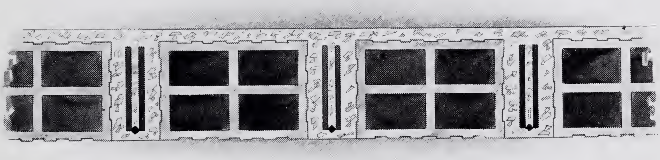
Load in Pounds	SPAN IN FEET										
	19	20	21	22	23	24	25	26	27	28	29
50	17.1	15.4	14.0	12.7	11.6	10.7	9.8	9.1	8.4	7.9	7.3
75	15.1	13.6	12.4	11.3	10.3	9.5	8.7	8.1	7.5	7.0	6.5
100	13.6	12.3	11.1	10.1	9.3	8.5	7.8	7.2	6.7		
125	12.3	11.1	10.1	9.2	8.4	7.7	7.1	6.6			
150	11.2	10.2	9.2	8.4	7.7	7.1	6.5				
175	10.4	9.4	8.5	7 7	7.1	6.5					
200	9.6	8.6	7.9	7.2	6.5						
250	8.4	7.6	6.9	6.3							
300	7.5	6.7									

$$\text{B. M.} = \frac{wl^2}{10}$$

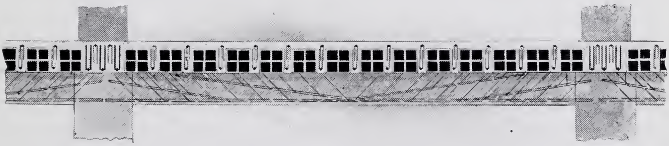
Maximum Spacing = 16″
Minimum Spacing = 7.2″
R. M. = 0.86 x 11 x 0.79 x 16000



Detail of Window Framing Into Concrete Lintel Beam.



Cross Section Reinforced Hollow Tile Floor.



Detail of Framing Reinforced Concrete Columns, Beams and Floors.

SAFE LIVE LOADS PER SQUARE FOOT FOR HOLLOW TILE FLOORS OF VARIOUS THICKNESSES

Reinforced with ½″ x 1½″ Kahn Trussed Bars

Depth	4″ Tile+ 1″ Concrete	4″ Tile+ 2″ Concrete	6″ Tile+ 1″ Concrete	6″ Tile+ 2″ Concrete	8″ Tile+ 1″ Concrete	8″ Tile+ 2″ Concrete	10″ Tile	10″ Tile+ 1″ Concrete	10″ Tile+ 2″ Concrete	12″ Tile	12″ Tile+ 1″ Concrete	12″ Tile+ 2″ Concrete
Weight of Floor in Pounds Per sq. Foot	38	50	47	59	56	68	54	66	78	63	75	87
Spacing	16″ C. to C.											
SPAN IN FEET 6	378	464	565	651	752	838	852	938	1024	1039	1125	1211
7	268	328	403	462	538	598	612	672	732	747	807	867
8	196	239	297	340	398	442	456	499	542	557	600	643
9	147	178	225	256	303	335	349	380	412	427	458	490
10	112	135	173	196	235	258	272	295	319	334	357	380
11	86	103	135	152	184	202	216	233	250	265	282	299
12	66	78	106	118	146	159	173	185	197	212	225	237
13		59	83	92	116	125	139	148	157	172	181	190
14		44	65	71	92	98	112	118	124	139	145	151
15		32	51	54	73	77	91	95	98	113	117	121
16			39	41	58	59	73	75	77	92	94	96
17			29	29	45	45	59	59	59	74	75	75
18					34	33	47	45	44	59	58	57
19					25		36	34	32	47	45	42
20							28			36	33	30
21										27		

$$B.\,M. = \frac{wl^2}{10}$$

SAFE LIVE LOADS PER SQUARE FOOT FOR HOLLOW TILE FLOORS OF VARIOUS THICKNESSES

Reinforced with $\frac{3}{4}''$ x $2\frac{3}{16}''$ and $1''$ x $3''$ Kahn Trussed Bars

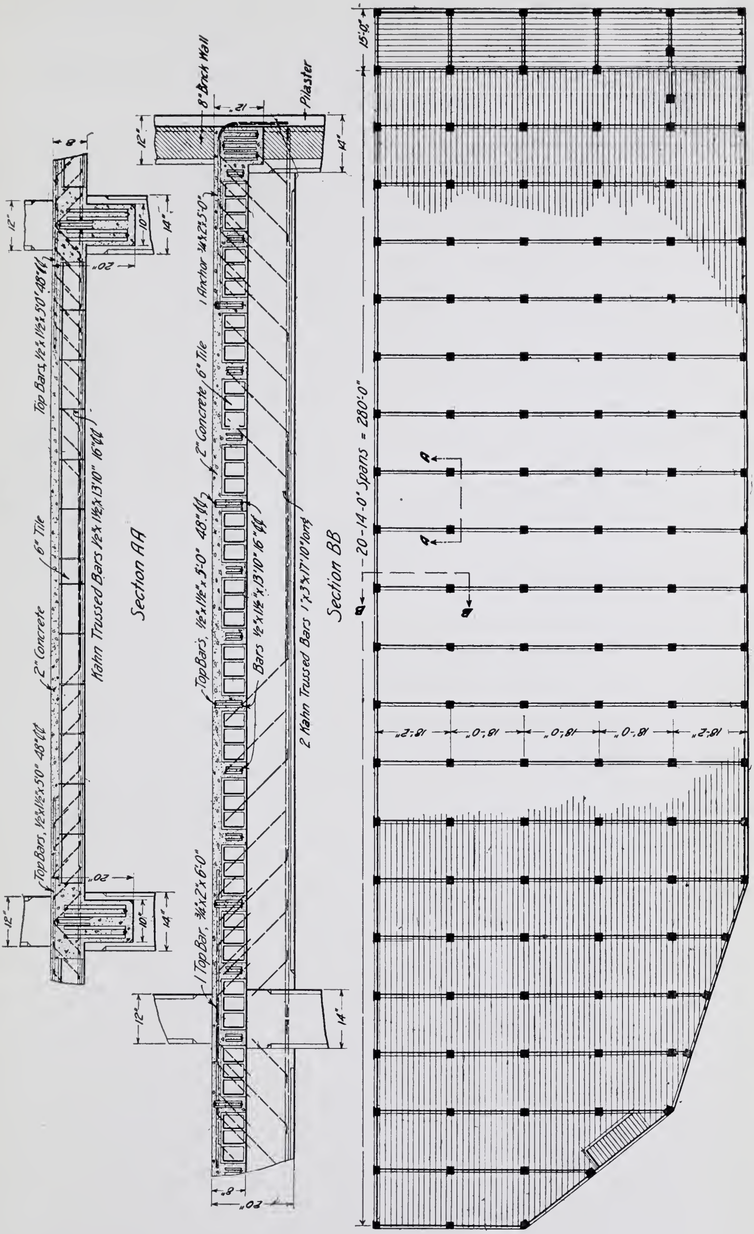
	$\frac{3}{4}''$ x $2\frac{3}{16}''$ Bars										1" x 3"
Depth	6" Tile + 2" Concrete	8" Tile + 2" Concrete	10" Tile + 2" Concrete	12" Tile + 2" Concrete	12" Tile + 2" Concrete	12" Tile + 2" Concrete	6" Tile + 2" Concrete	8" Tile + 2" Concrete	10" Tile + 2" Concrete	12" Tile + 2" Concrete	12" Tile + 3" Concrete
Weight of Floor in Pounds Per Sq. Foot	59	68	78	87	98	104	61	71	82	92	108
Spacing	<—16"C to C—>				15"	13"	<—17"C to C—>				18"
SPAN IN FEET 8	686	887	1090	1293	1374	1595	639	827	1018	1208	2167
9	528	687	845	1003	1065	1238	492	638	786	935	1687
10	416	543	669	796	844	983	387	504	621	739	1347
11	334	437	540	643	681	795	309	404	499	595	1094
12	271	357	441	526	556	651	250	329	406	485	902
13	222	294	364	436	459	539	204	269	334	399	752
14	182	244	303	363	383	451	167	222	276	332	634
15	152	204	254	306	321	379	138	185	230	277	538
16	127	171	214	257	270	320	114	154	193	233	460
17	106	144	181	218	228	272	94	128	161	196	395
18	88	121	153	185	193	231	77	107	135	165	341
19	73				163	197	63	88	113	138	295
20	60				137	167	51	73	94	116	256
21	49				116	142		59	77	97	222
22	39				97	121		48	63	80	192
23					80	101		38	51	65	167
24					66	85		29	40	52	145
25					53	70			30	41	125
26					41	57				31	107
27					31	45					92
28											78
29											65
$B.M.=\frac{wl^2}{10}$					10" Tile On Edge	8" Tile On Edge					

SAFE LIVE LOADS PER SQUARE FOOT FOR HOLLOW TILE FLOORS OF VARIOUS THICKNESSES

Reinforced with ½″ x 1½″ and ¾″ x $2\frac{3}{16}$″ Kahn Trussed Bars Spaced Alternately

Depth	4″ Tile + 2″ Concrete	6″ Tile + 1″ Concrete	6″ Tile + 2″ Concrete	8″ Tile + 1″ Concrete	8″ Tile + 2″ Concrete	10″ Tile + 1 Concrete	10″ Tile + 2″ Concrete	12″ Tile + 1″ Concrete	12″ Tile + 2″ Concrete
Weight of Floor in Pounds Per Sq. Foot	50	98	59	56	68	66	78	75	87
Spacing	<——16″ C. to C.——>								
SPAN IN FEET 7	447	583	678	787	880	987	1080	1189	1282
8	353	435	505	589	658	740	809	893	961
9	267	334	387	454	505	571	623	690	741
10	206	262	302	357	396	450	489	544	584
11	163	208	239	285	316	360	391	437	467
12	129	167	191	231	255	292	316	355	379
13	103	135	154	188	207	239	258	291	310
14	82	110	125	155	169	197	212	241	255
15	64	90	101	128	138	163	174	200	211
16		73	82	105	113	136	144	167	175
17		60	66	87	93	113	118	139	145
18			52	71	75	93	97	116	120
19			41	58	61	77	79	97	99
20			31	47	48	63	64	80	81
21				38	37	51	51	65	65
22				29	28	41	39	53	52
23						32	29	42	40
24								32	29
25									

$$B.M. = \frac{wl^2}{10}$$



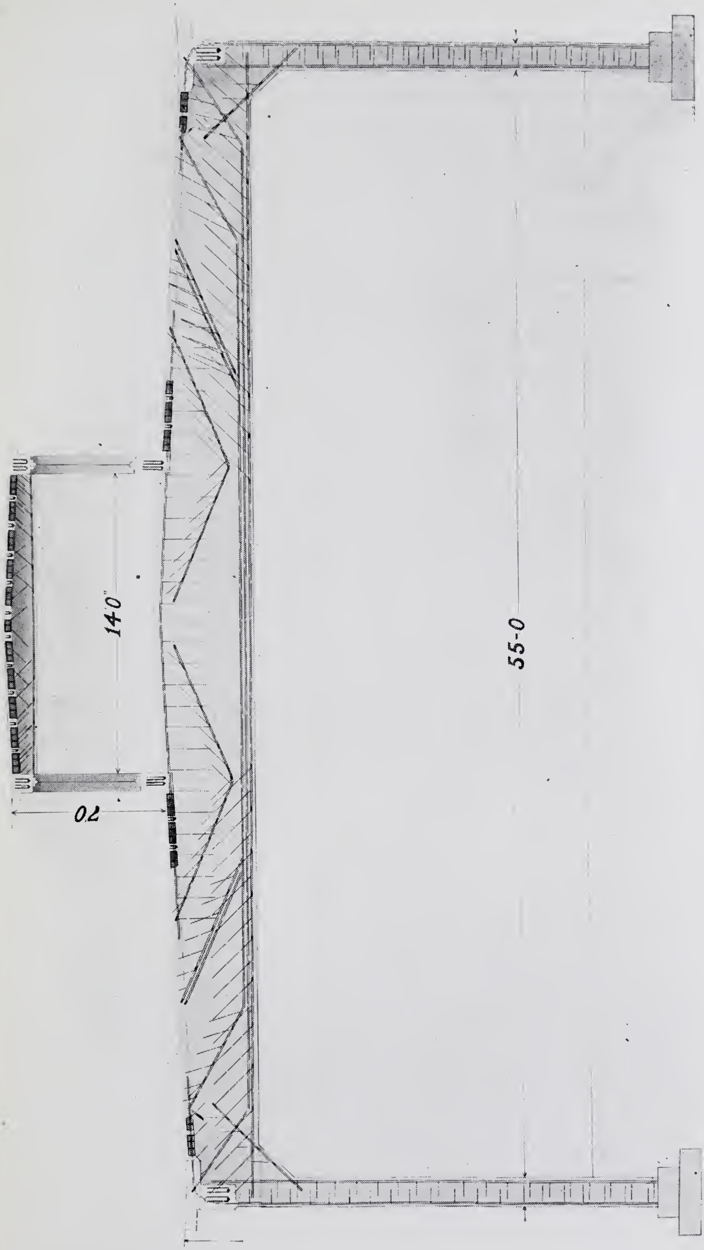
Showing Floor Plan and Typical Slab Construction Anderson Carriage Co.
Detroit, Mich. Geo. D. Mason, Architect.

SAFE LIVE LOAD PER SQUARE FOOT FOR HOLLOW TILE FLOORS OF VARIOUS THICKNESSES

Reinforced with ½″ x 1½″ and ¾″ x $2\frac{3}{16}$″ Kahn Trussed Bars Spaced Alternately

Depth		4″ Tile+ 2″ Concrete	6″ Tile+ 1″ Concrete	6″ Tile+ 2″ Concrete	8″ Tile+ 1″ Concrete	8″ Tile+ 2″ Concrete	10″ Tile+ 1″ Concrete	10″ Tile+ 2″ Concrete	12″ Tile+ 1″ Concrete	12″ Tile+ 2″ Concrete
Weight of Floor in Pounds Per Sq. Foot		51	49	60	59	71	70	82	80	92
Spacing		<— 17″ C. to C. —>								
SPAN IN FEET	7	446	544	635	734	821	921	1008	1109	1196
	8	329	405	472	548	612	689	753	830	894
	9	250	310	361	421	469	529	577	639	687
	10	193	242	280	330	366	416	452	503	539
	11	151	191	222	262	290	331	359	402	430
	12	119	153	177	211	233	267	289	325	346
	13	94	123	142	171	188	217	234	265	281
	14	74	99	114	139	152	178	191	217	230
	15	58	80	92	114	123	146	155	179	188
	16		65	74	93	100	120	127	148	155
	17		51	59	76	80	98	103	122	126
	18			46	61	64	80	83	100	103
	19			35	49	50	64	66	81	83
	20				38	38	51	52	66	66
	21				29	28	40	39	52	51
	22						30	28	40	38
	23								30	27

$$B.\ M. = \frac{wl^2}{10}$$



Cross Section, Long Span Roof Girder. Garage Geo. N. Pierce Factory, Buffalo, N. Y. Lockwood, Green & Co. and Albert Kahn, Architects. Concrete Steel & Tile Construction Co., Contractors.

EXPLANATION OF TABLES OF SAFE LOADS FOR KAHN BAR BEAMS.

The tables for beams on pages 59 to 63 give the loads which a beam will safely carry, distributed uniformly over its length. These loads include the weight of the beams, which must be deducted in order to arrive at the net load which the beam will carry. The carrying capacity in this table is based on beams freely supported at the ends that is, *B. M.* $\frac{wl.}{8}$. In building construction it is usual to take advantage of continuous action and to provide reinforcement at the top of the beam over the support. For beams continuous at both ends the bending moment at the center of the span may be taken as $\frac{wl}{10}$ **in which case the safe loads as given in the tables should be increased 25 per cent.**

Where the area of the steel reinforcement exceeds 1 per cent. of the area of the concrete above the steel the beam must be made of T section. This can readily be done by using table on page (29) for ratio of width of T to width of beam.

For beams carrying plastered ceilings it is found by experience that their depth should be at least 1-15 of the clear span. Where this limit is exceeded there is danger of the ceiling cracking.

These tables show the sizes of beams to which the various section of Kahn Bars are adopted. For loadings that exceed those given in the table, one or more bars are added to the beam. The widths of beams shown are sufficient to accommodate a center bar, but where more than one bar is added the width of beam must be increased.

Kahn Reinforced Hollow Tile Floor Construction.

SAFE TOTAL LOAD IN HUNDREDS OF POUNDS UNIFORMLY DISTRIBUTED FOR CONCRETE BEAMS

Reinforced with Two ¾″ x $2\frac{3}{16}$″ Kahn Trussed Bars
Area = 1.58 sq. in.

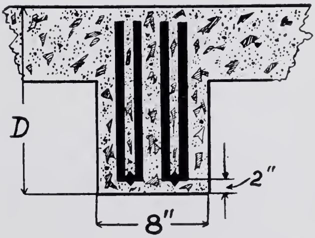
SPAN IN FEET	DEPTH IN INCHES (*D*)					
	8	10	12	14	16	18
6	169	217	266	314	362	411
7	145	186	228	269	310	352
8	127	163	199	236	272	308
9	113	145	177	209	242	274
10	101	130	159	188	217	246
11		119	145	171	198	224
12		109	133	157	181	205
13			123	145	167	190
14			114	135	155	176
15			106	126	145	164
16				118	136	154
17				111	128	145
18					121	137
19					114	130
20					109	123
21						117
22						112

NOTE:—Make Beam of T Section.

D=Total depth of Beam in inches.

$$B.M. = \frac{1}{8} wl^2$$

NOTE:—For loads above heavy line beam must be reinforced for shear.



SAFE TOTAL LOADS IN HUNDREDS OF POUNDS UNIFORMLY DISTRIBUTED FOR CONCRETE BEAMS

Reinforced with Two 1″ x 3″ Kahn Trussed Bars.
Area = 2.82 sq. in.

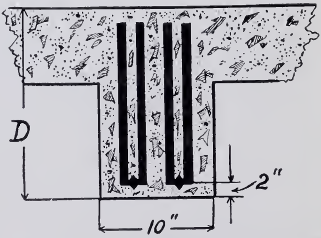
SPAN IN FEET	DEPTH IN INCHES (*D*)									
	12	14	16	18	20	22	24	26	28	30
12	216	259	302	345	388	431	474	517	560	603
13	199	239	278	318	358	398	438	477	517	557
14	185	222	259	296	332	370	406	443	480	517
15	172	207	241	276	310	345	379	414	448	483
16		194	226	259	291	323	356	388	420	453
17		182	213	244	274	304	335	365	396	426
18		172	201	230	258	287	316	345	374	402
19			190	218	245	272	300	327	354	381
20			181	207	233	258	284	310	336	362
21				197	222	246	271	295	320	345
22				188	212	235	259	282	305	329
23					202	225	247	270	292	315
24					194	216	237	258	280	302
25					186	207	228	248	269	290
26						199	219	239	258	278
27						191	211	230	249	268
28							203	221	240	258
29							196	214	232	250
30							189	207	224	241
31								200	217	233
32								194	210	226
33									204	219
34									198	213
35									192	207
36										201
37										196

NOTE:—Make Beam of T Section.

$$B.M. = \frac{wl^2}{8}$$

D=Total depth of Beam in inches.

NOTE:—For loads above heavy line beam must be reinforced for shear.



SAFE TOTAL LOADS IN HUNDREDS OF POUNDS UNIFORMLY DISTRIBUTED FOR CONCRETE BEAMS

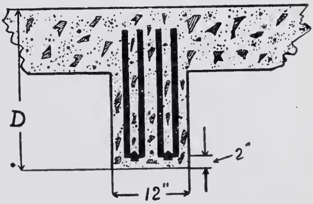
Reinforced with Two 1¾″ x 2¾″ Kahn Trussed Bars. Area=4 sq. in.

SPAN IN FEET	DEPTH IN INCHES (*D*)									
	16	18	20	22	24	26	28	30	32	34
16	321	367	413	459	504	550	596	642	688	734
17	302	345	389	432	475	518	561	604	647	690
18	285	326	367	408	448	489	530	571	612	652
19	270	309	348	386	425	463	502	541	579	618
20	257	294	330	367	404	440	477	514	550	587
21		280	314	349	384	419	454	489	524	559
22		267	300	334	367	400	434	467	500	534
23			287	319	351	383	415	447	479	510
24			275	306	336	367	398	428	459	489
25			264	294	323	352	382	411	440	470
26				282	310	339	367	395	423	452
27				272	299	326	353	380	408	435
28					288	314	341	361	393	419
29					278	304	329	354	380	405
30					269	294	318	342	367	391

NOTE:—

Make Beam of T Section.

D = Total depth of Beam in inches.



$$B.M. = \frac{wl^2}{8}$$

NOTE:—For loads above heavy line beam must be reinforced for shear.

SAFE TOTAL LOADS IN HUNDREDS OF POUNDS UNIFORMLY DISTRIBUTED FOR CONCRETE BEAMS

Reinforced with Two 2″ x 3½″ Kahn Trussed Bars
Area=6 sq. in.

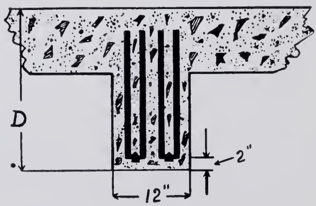
Span in Feet	DEPTH IN INCHES (*D*)						
	18	20	22	24	26	28	30
12	734	826	917	1009	1101	1193	1284
13	677	762	847	931	1016	1101	1185
14	629	708	786	865	944	1022	1101
15	587	660	734	807	881	954	1027
16	550	619	688	757	826	894	963
17	518	583	648	712	777	842	907
18	489	550	612	673	734	795	856
19	463	521	579	637	695	753	811
20	440	495	550	605	660	716	771
21	419	472	524	577	629	681	734
22	400	450	500	550	600	650	701
23		431	479	526	574	622	670
24		413	459	505	550	596	642
25		396	440	484	528	572	616
26			423	466	508	550	593
27			408	448	489	530	571
28				432	472	511	550
29				418	456	493	531
30				404	440	477	514
31					426	462	497
32					413	447	482
33						434	467
34						421	453
35						409	440
36							428
37							417

NOTE:—Make Beam of T Section.

D=Total depth of Beam in inches.

$$B.M.=\frac{1}{8}wl^2$$

Note: — For loads above heavy line beam must be reinforced for shear.



SAFE LOADS FOR REINFORCED CONCRETE COLUMNS

Size of Columns	Kahn Bars		Stress per sq. in. (*C*) on concrete in lbs. 300	350	400	500	600
10x10	4U	½x1½	36900	43000	49200	61500	73800
12x12	4U	½x1½	50100	58400	66800	83500	100200
12x12	4U	¾x2	56500	65900	75300	94100	112900
14x14	4U	¾x2	72100	84100	96100	120100	144100
16x16	4S	¾x2	86200	100500	114900	143600	172400
16x16	4U	¾x2	90100	105100	120100	150100	180100
18x18	4S	1 x3	114000	133000	152000	190000	228000
18x18	4U	1 x3	120900	141000	161200	201500	241800
20x20	4S	1 x3	136800	159600	182400	228000	273600
20x20	4U	1 x3	143700	167600	191600	239500	287400
22x22	4S	1 x3	162000	189000	216000	270000	324000
22x22	4U	1 x3	168900	197000	225200	281500	337800
24x24	4S	1¾x2¾	199600	232900	266200	332800	399300
24x24	4U	1¾x2¾	206400	240800	275200	344000	412800
26x26	4S	1¾x2¾	229600	267900	306200	382800	459300
26x26	4U	1¾x2¾	236400	275800	315200	394000	472800
28x28	4S	1¾x2¾	262000	305700	349400	436800	524100
28x28	4U	1¾x2¾	268800	313600	358400	448000	537600
30x30	4S	1¾x2¾	296800	346300	395800	494800	593100
30x30	4U	1¾x2¾	303600	354200	404800	506000	607200
32x32	4S	1¾x2¾	334000	389700	445400	556800	668100
32x32	4U	1¾x2¾	340800	397600	454400	568000	681600
34x34	4S	1¾x2¾	373600	435900	498200	622800	747300
34x34	4U	1¾x2¾	380400	445800	507200	634000	760800
36x36	4S	1¾x2¾	415600	484900	554200	692800	831300
36x36	4U	1¾x2¾	422400	492800	563200	704000	844800

Above loading is computed by formula:—

Safe load $= C\ (Ac + 15\ As)$

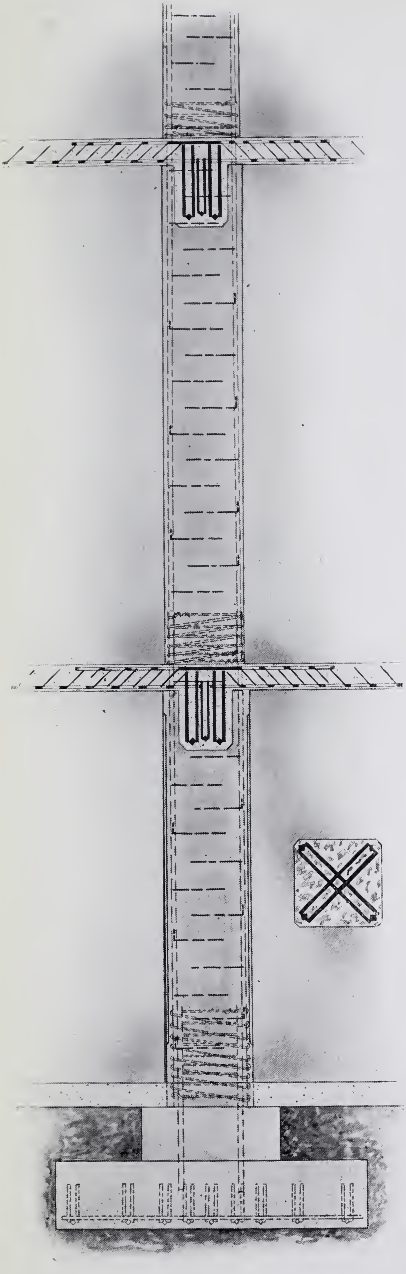
Ac = Net area of concrete — S = Sheared Kahn Bars

As = Area of steel — U = Unsheared " "

The least diameter of the column should in no case be less than $\frac{1}{15}$ the clear height.

SAFE LOADS CARRIED BY HOOPED COLUMNS

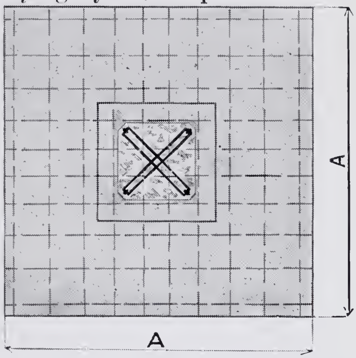
SAFE LOADS In Pounds	Outside Diameter	Core Diameter	Number of Verticals	Size of Verticals	Size of Hooping	Pitch of Hooping
107100	14″	10″	6	½″ square	5/16 ø	2″
118000	14″	10″	6	½″ square	5/16″ ø	1½″
139500	16″	12″	6	½″ square	5/16″ ø	2″
152500	16″	12″	6	½″ square	5/16″ ø	1½″
185500	18″	14″	6	⅝″ square	5/16″ ø	2″
200700	18″	14″	6	⅝″ square	5/16″ ø	1½″
260200	20″	16″	6	⅝″ square	½″ x ¼″	2″
288500	20″	16″	6	⅝″ square	½″ x ¼″	1½″
268400	20″	16″	8	⅝″ square	½″ x ¼″	2″
296700	20″	16″	8	⅝″ square	½″ x ¼″	1½″
321700	22″	18″	6	¾″ square	½″ x ¼″	2″
353500	22″	18″	6	¾″ square	½″ x ¼″	1½″
319100	22″	18″	8	⅝″ square	½″ x ¼″	2″
350900	22″	18″	8	⅝″ square	½″ x ¼″	1½″
389800	24″	20″	6	⅞″ square	½″ x ¼″	2″
425100	24″	20″	6	⅞″ square	½″ x ¼″	1½″
388800	24″	20″	8	¾″ square	½″ x ¼″	2″
424100	24″	20″	8	¾″ square	½″ x ¼″	1½″
448900	26″	22″	8	¾″ square	½″ x ¼″	2″
487800	26″	22″	8	¾″ square	½″ x ¼″	1½″
460700	26″	22″	10	¾″ square	½″ x ¼″	2″
499600	26″	22″	10	¾″ square	½″ x ¼″	1½″
530800	28″	24″	8	⅞″ square	½″ x ¼″	2″
573200	28″	24″	8	⅞″ square	½″ x ¼″	1½″
525500	28″	24″	10	¾″ square	½″ x ¼″	2″
567900	28″	24″	10	¾″ square	½″ x ¼″	1½″
619900	30″	26″	8	1″ square	1″ x ¼″	4″
665800	30″	26″	8	1″ square	1″ x ¼″	3″
616300	30″	26″	10	⅞″ square	1″ x ¼″	4″
662200	30″	26″	10	⅞″ square	1″ x ¼″	3″
694200	32″	28″	8	1″ square	1″ x ¼″	4″
743600	32″	28″	8	1″ square	1″ x ¼″	3″
690600	32″	28″	10	⅞″ square	1″ x ¼″	4″
740000	32″	28″	10	⅞″ square	1″ x ¼″	3″
795400	34″	30″	8	1⅛″ square	1″ x ¼″	4″
848400	34″	30″	8	1⅛″ square	1″ x ¼″	3″
794100	34″	30″	10	1″ square	1″ x ¼″	4″
847100	34″	30″	10	1″ square	1″ x ¼″	3″



Typical Column Detail

FOOTING TABLES

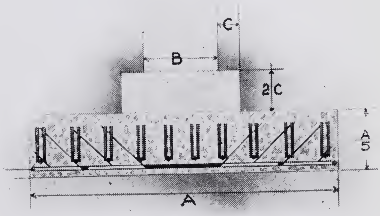
The tables given on pages 66 to 70 are for square footings. Soil values from 1 to 5 tons have been assumed, and the footings figured for column loads from 75,000 pounds to 600,000 pounds varying by 25,000 pounds.



Typical Column Footing Plan.

The tables show the total number of Kahn Bars required in each footing, half the number shown being placed in each direction.

The footing tables are figured for a depth of footing slab equal to one-fifth the width. The cap at the foot of the column is to have a projection "c" from the face of the column of 6″ for columns less than 24″ in least diameter and 8″ where the column is 24″ and over. The depth of the cap should be twice this projection.



Typical Column Footing Elevation

TABLE OF FOOTINGS

Soil Value per Sq. Foot	2000 Pounds		2500 Pounds	
Load on Footing	Size of Footing	Kahn Trussed Bars	Size of Footing	Kahn Trussed Bars
75000	6′3″ sq.	10–¾″x2$\frac{3}{16}$″	5′6″ sq.	10–¾″x2$\frac{3}{16}$″
100000	7′3″ "	12– "	6′6″ "	12– "
125000	8′0″ "	14– "	7′3″ "	14– "
150000	8′9″ "	16– "	7′9″ "	16– "
175000	9′6″ "	12–1″x3″	8′6″ "	18– "
200000	10′0″ "	14 "	9′0″ "	12–1″x3″
225000	10′9″ "	18– "	9′6″ "	14– "
250000	11′3″ "	20– "	10′0″ "	18– "
275000	11′9″ "	20– "	10′6″ "	20– "
300000	12′3″ "	22– "	11′0″ "	20– "
325000	12′9″ "	22– "	11′6″ "	22– "
350000	13′3″ "	22– "	11′9″ "	22– "
375000	13′9″ "	24– "	12′3″ "	22– "
400000	14′0″ "	24– "	12′9″ "	24– "
425000	14′6″ "	26– "	13′0″ "	24– "
450000	15′0″ "	28– "	13′6″ "	26– "
475000	15′6″ "	28– "	13′9″ "	28– "
500000	15′9″ "	30– "	14′3″ "	28– "
525000	16′3″ "	30– "	14′6″ "	30– "
550000	16′9″ "	32– "	14′9″ "	30– "
575000	17′0″ "	32– "	15′3″ "	32– "
600000	17′3″ "	34– "	15′6″ "	32– "

TABLE OF FOOTINGS

Soil Value per Sq. Foot	3000		4000	
Load on Footing	Size of Footing	Kahn Trussed Bars	Size of Footing	Kahn Trussed Bars
75000	5′0″ sq.	10–$\frac{3}{4}$″x2$\frac{3}{16}$″	4′6″ sq.	8–$\frac{3}{4}$″x2$\frac{3}{16}$″
100000	6′0″ "	12– "	5′0″ "	10– "
125000	6′6″ "	14– "	5′9″ "	12– "
150000	7′3″ "	16– "	6′3″ "	14– "
175000	7′9″ "	18– "	6′9″ "	16– "
200000	8′3″ "	18– "	7′3″ "	18– "
225000	8′9″ "	14–1″x3″	7′6″ "	18– "
250000	9′3″ "	14– "	8′0″ "	14–1″x3″
275000	9′9″ "	16– "	8′6″ "	14– "
300000	10′0″ "	18– "	8′9″ "	16– "
325000	10′6″ "	20– "	9′0″ "	16– "
350000	10′9″ "	22– "	9′6″ "	16– "
375000	11′3″ "	22– "	9′9″ "	18– "
400000	11′6″ "	22– "	10′0″ "	20– "
425000	12′0″ "	24– "	10′3″ "	22– "
450000	12′3″ "	26– "	10′9″ "	24– "
475000	12′9″ "	26– "	11′0″ "	24– "
500000	13′0″ "	28– "	11′3″ "	26– "
525000	13′3″ "	28– "	11′6″ "	26– "
550000	13′6″ "	30– "	11′9″ "	28– "
575000	13′9″ "	32– "	12′0″ "	28– "
600000	14′3″ "	32– "	12′3″ "	30– "

TABLE OF FOOTINGS

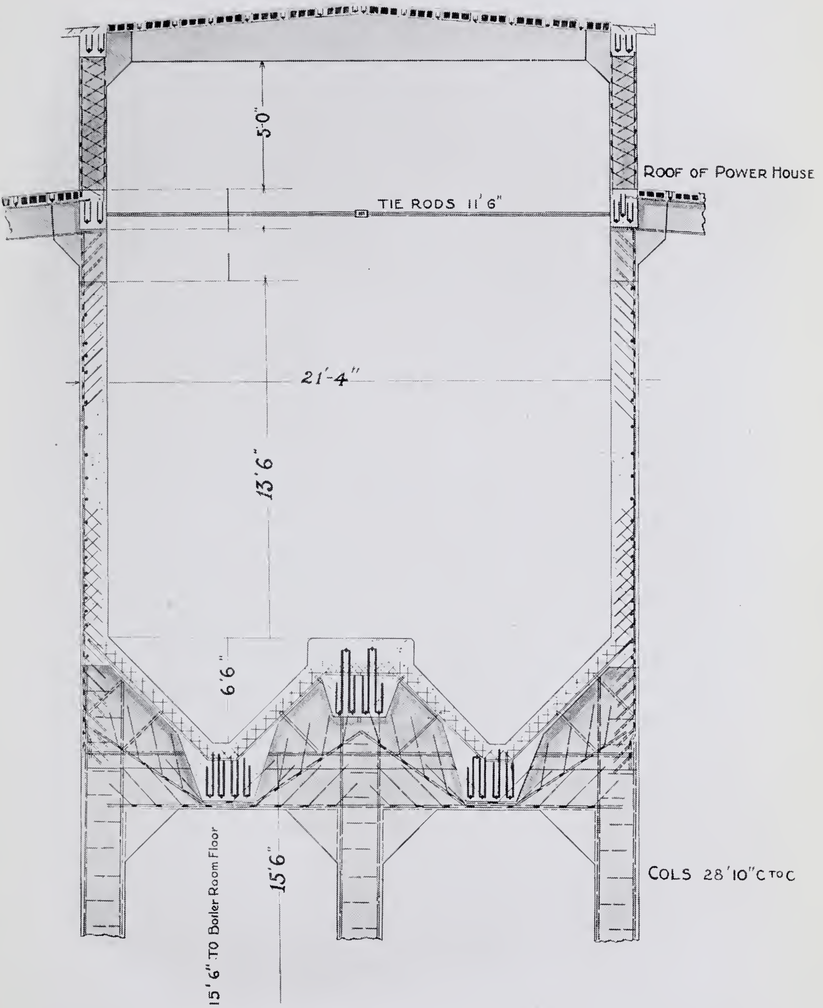
Soil Value per Sq. Foot	5000 Pounds		6000 Pounds	
Load on Footing	Size of Footing	Kahn Trussed Bars	Size of Footing	Kahn Trussed Bars
75000	4′0″ sq.	12–½″x1½″		
100000	4′6″ "	10–¾″x2$\frac{3}{16}$″	4′3″ sq.	10–¾″x2$\frac{3}{16}$″
125000	5′0″ "	12– "	4′9″ "	10– "
150000	5′6″ "	12– "	5′0″ "	12– "
175000	6′0″ "	14– "	5′6″ "	14– "
200000	6′6″ "	16– "	5′9″ "	14– "
225000	6′9″ "	18– "	6′3″ "	16– "
250000	7′3″ "	20– "	6′6″ "	18– "
275000	7′6″ "	20– "	6′9″ "	20– "
300000	7′9″ "	14–1″x3″	7′3″ "	14–1″x3″
325000	8′0″ "	14– "	7′6″ "	14– "
350000	8′6″ "	14– "	7′9″ "	14– "
375000	8′9″ "	16– "	8′0″ "	14– "
400000	9′0″ "	16– "	8′3″ "	14– "
425000	9′3″ "	16– "	8′6″ "	16– "
450000	9′6″ "	18– "	8′9″ "	18– "
475000	9′9″ "	18– "	9′0″ "	18– "
500000	10′0″ "	22– "	9′3″ "	18– "
525000	10′3″ "	24– "	9′6″ "	20– "
550000	10′6″ "	24– "	9′9″ "	22– "
575000	10′9″ "	26– "	9′9″ "	22– "
600000	11′0″ "	28– "	10′0″ "	24– "

TABLE OF FOOTINGS

Soil Value per Sq. Foot	7000 Pounds		8000 Pounds	
Load on Footing	Size of Footing	Kahn Trussed Bars	Size of Footing	Kahn Trussed Bars
100000	4′0″ sq.	14–½″x1½″		
125000	4′3″ "	10–¾″x2$\frac{3}{16}$″	4′0″ sq.	14–½″x1½″
150000	4′9″ "	12– "	4′6″ "	10–¾″x2$\frac{3}{16}$″
175000	5′0″ "	12– "	4′9″ "	12– "
200000	5′6″ "	14– "	5′0″ "	12– "
225000	5′9″ "	16– "	5′6″ "	16– "
250000	6′0″ "	16– "	5′9″ "	16– "
275000	6′3″ "	18– "	6′0″ "	16– "
300000	6′6″ "	18– "	6′3″ "	18– "
325000	6′9″ "	20– "	6′6″ "	18– "
350000	7′0″ "	20– "	6′9″ "	20– "
375000	7′3″ "	12–1″x3″	7′0″ "	20– "
400000	7′6″ "	12– "	7′0″ "	20– "
425000	7′9″ "	14– "	7′3″ "	12–1″x3″
450000	8′0″ "	16– "	7′6″ "	14– "
475000	8′3″ "	16– "	7′9″ "	14– "
500000	8′6″ "	16– "	8′0″ "	16– "
525000	8′9″ "	18– "	8′3″ "	16– "
550000	9′0″ "	18– "	8′3″ "	16– "
575000	9′0″ "	18– "	8′6″ "	18– "
600000	9′3″ "	20– "	8′9″ "	18– "

TABLE OF FOOTINGS

Soil Value per Sq. Foot	9000 Pounds		10,000 Pounds	
Load on Footing	Size of Footing	Kahn Trussed Bars	Size of Footing	Kahn Trussed Bars
150000	4′3″ sq.	10–¾″x2$\frac{3}{16}$″	4′0″ sq.	14-½″x1½″
175000	4′6″ "	12– "	4′3″ "	12–¾″x2$\frac{3}{16}$″
200000	4′9″ "	12– "	4′6″ "	10– "
225000	5′0″ "	14– "	4′9″ "	12– "
250000	5′3″ "	14– "	5′0″ "	14– "
275000	5′6″ "	14– "	5′3″ "	14– "
300000	5′9″ "	16– "	5′6″ "	14– "
325000	6′0″ "	16– "	5′9″ "	16– "
350000	6′3″ "	16– "	6′0″ "	16– "
375000	6′6″ "	18– "	6′3″ "	16– "
400000	6′9″ "	18– "	6′3″ "	16– "
425000	7′0″ "	20– "	6′6″ "	18– "
450000	7′0″ "	20– "	6′9″ "	18– "
475000	7′3″ "	14–1″x3″	7′0″ "	20– "
500000	7′6″ "	14– "	7′0″ "	20– "
525000	7′9″ "	16– "	7′3″ "	14–1″x3″
550000	7′9″ "	16– "	7′6″ "	14– "
575000	8′0″ "	16– "	7′6″ "	14– "
600000	8′3″ "	18– "	7′9″ "	16– "



Coal Bin.
Diamond Crystal Salt Co., St. Clair, Mich.
Weil & Shaw, Engineers. James O'Sullivan, Contractor.

EXPLANATION OF TABLES FOR BIN DESIGN.

These tables are taken from:

"Some Formulae and Tables for Bin Designing."

R. W. DULL, M. E.

Engineering News, Vol. LII, No. 3, July 21, 1904.

See above article for complete discussion of the theory on which these tables are based.

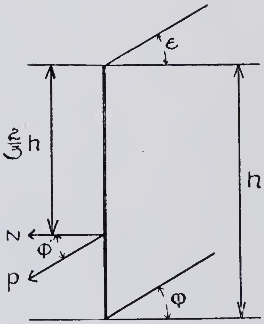
ϕ = angle of repose of material.

ϕ' = angle of friction between material and bin-wall = angle between direction of thrust and normal to bin-wall.

P = total thrust against bin-wall.

N = horizontal component of P.

E = angle of slope of surface of material.



TABLES OF PRESSURES ON VERTICAL BIN-WALLS.

See page 73

Column 1 gives the normal component of the total pressure on the (vertical) side, when the surface of the material is level.

$$N = \left(\frac{\operatorname{Cos} \phi}{n+1}\right)^2 \frac{Wh^2}{2} \quad \text{where } n = \sqrt{\frac{\sin(\phi+\phi')\sin\phi}{\cos\phi'}}$$

Column 2 gives the pressure against the vertical plane AB, when angle of friction is not considered, *i. e.*, $\phi' = 0$

$$N = \frac{Wh^2}{2} \tan^2\left(45^\circ - \frac{\phi}{2}\right)$$

Column 3 gives the normal component of total pressure on the vertical side when the surface of the material is surcharged to the angle of repose, and the bin is unlimited in horizontal extent.

$$N = \operatorname{Cos}^2 \phi \, \frac{Wh^2}{2}$$

Column 4 gives the same as Column 3, but for the case where friction is neglected, *i. e.*, $\phi' = \phi$

$$E = \phi. \quad P = \cos\phi \, \frac{Wh^2}{2}$$

Column 5 gives the normal component of the total pressure on the vertical side when the material slopes downward along the angle of repose, *i. e.*, $\phi' = \phi$

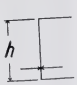
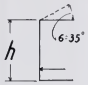
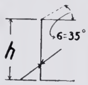
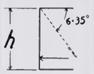
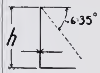
$$N = \left(\frac{\cos\phi}{n+1}\right)^2 \frac{Wh^2}{2} \quad \text{where } n = \sqrt{\frac{\sin(\phi+\phi')\ \sin(\phi+E)}{\cos\phi'\ \cos E}}$$

Column 6 gives the same as Column 5, but for the case where friction is neglected, *i. e.*, $\phi' = 0$.

TOTAL PRESSURE FOR DEPTH "h" FOR BITUMINOUS COAL IN VERTICAL BINS

Wt. per Cu. Ft.=50 lbs. Angle of repose=ø=35°.

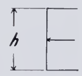
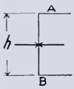
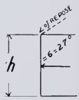
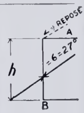
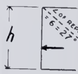
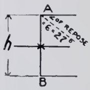
NOTE:—THESE PRESSURES ARE FOR A SECTION OF MATERIAL ONE FOOT WIDE

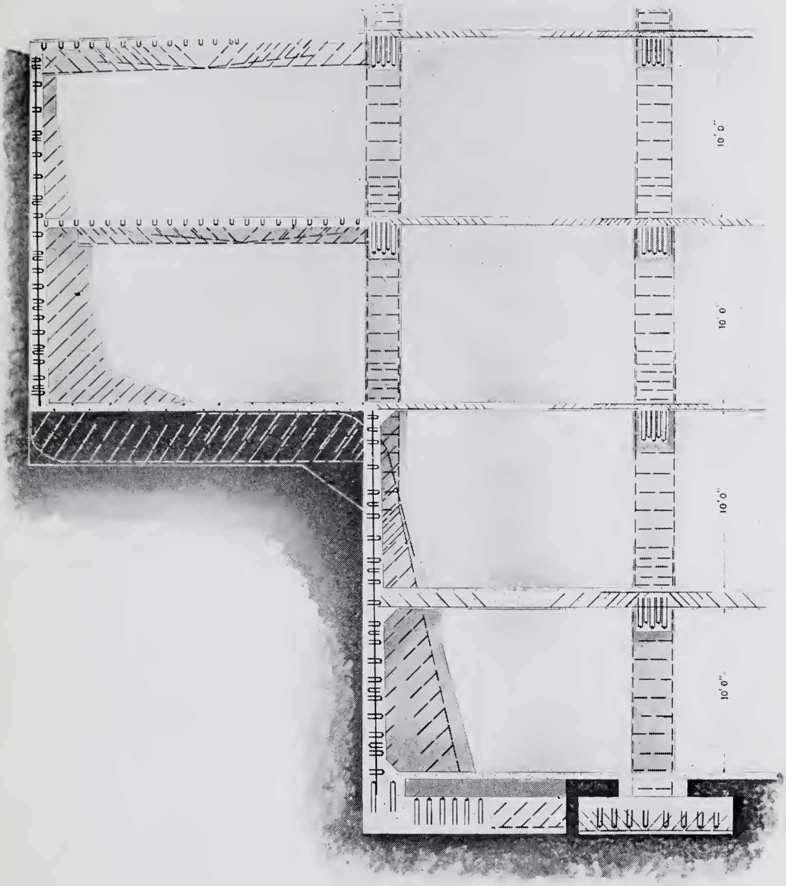
Depth in Feet	1	2	3	4	5	6
						
	ø′=18°	ø′=o	E=ø	E=ø	E=ø	E=ø
1	6	7	17	20	4	5
2	23	27	67	82	17	20
3	52	61	151	184	38	46
4	93	108	268	328	68	82
5	146	169	419	513	107	128
6	209	243	603	738	156	184
7	286	333	821	1005	209	257
8	373	432	1072	1312	273	328
9	472	547	1357	1661	346	415
10	583	675	1675	2050	427	513
11	705	817	2027	2481	516	615
12	840	972	2412	2952	615	738
13	985	1141	2831	3465	722	866
14	1143	1323	3283	4018	838	1005
15	1312	1519	3769	4613	960	1152
16	1492	1728	4288	5248	1093	1311
17	1685	1951	4841	5945	1232	1480
18	1889	2187	5427	6642	1382	1660
19	2105	2437	6047	7400	1541	1852
20	2332	2700	6700	8200	1708	2052
21	2571	2977	7387	9041	1883	2262
22	2821	3267	8102	9922	2067	2483
23	3084	3571	8861	10845	2259	2560
24	3358	3888	9648	11808	2460	2810
25	3644	4219	10469	12813	2669	3206
26	3941	4563	11323	13858	2887	3468
27	4250	4923	12211	14945	3113	3740
28	4570	5292	13142	16072	3348	4022
29	4903	5677	14087	17241	3591	4314
30	5247	6075	15075	18450	3843	4617

TOTAL PRESSURE FOR DEPTH "*h*" FOR ANTHRACITE COAL IN VERTICAL BINS

Wt. per Cu. Ft.=52 Lbs. Angle of Repose=ø=27°

NOTE—THESE PRESSURES ARE FOR A SECTION OF MATERIAL ONE FOOT WIDE

Depth in Feet	1	2	3	4	5	6
						
	ø′=16°	ø′=o°	E=ø	E=ø	E=ø	E=ø
1	8	10	20	23	6	8
2	33	39	82	93	25	31
3	75	88	184	209	57	69
4	134	156	328	371	102	122
5	210	244	513	579	159	191
6	302	351	738	834	230	267
7	411	478	1005	1135	313	374
8	536	624	1312	1482	402	489
9	680	790	1661	1876	517	619
10	839	975	2050	2317	638	764
11	1014	1180	2481	2802	773	925
12	1209	1405	2952	3340	920	1100
13	1418	1648	3465	3918	1080	1290
14	1643	1910	4018	4540	1250	1497
15	1887	2193	4613	5220	1436	1720
16	2145	2500	5248	5930	1636	1953
17	2421	2808	5945	6696	1845	2207
18	2718	3160	6642	7507	2064	2471
19	3030	3521	7400	8363	2310	2758
20	3350	3902	8200	9268	2554	3053
21	3700	4303	9041	10218	2820	3372
22	4061	4718	9922	11214	3086	3701
23	4438	5156	10845	12257	3372	4040
24	4833	5611	11808	13346	3680	4398
25	5244	6097	12813	14481	3985	4770
26	5672	6600	13858	15663	4521	5160
27	6116	7112	14945	16891	4650	5560
28	6578	7638	16072	18165	5000	5979
29	7056	8202	17241	19486	5370	6421
30	7551	8775	18450	20853	5742	6880



Cross Section Retaining Wall for Broadway Warehouse, Cleveland, Ohio.
W. Kingsley, Architect. Masters & Mullen, Contractors.

NOTE:—This building is eight stories high but only four floors show above the street level at the front. The retaining wall is 20 feet high from the footing level to the second floor level, the face being on the building line. The third floor is excavated under the sidewalk to the curb line with a second 20 foot retaining wall running to the pavement. The lower wall is 16 inches thick at the bottom, 10 inches at the top with the upper wall 14 and 8 inches.

EARTH PRESSURES

Angle of Repose = ø = 33 Degrees

Depth	Total Inclined Press.	Total Hor. Press.	Hor. Press. per Sq. Foot	Depth	Total Inclined Press.	Total Hor. Press.	Hor. Press. per Sq. Foot
5	335	280	112	23	7080	5935	516
6	480	405	135	24	7710	6460	538
7	655	550	157	25	8365	7015	561
8	855	720	180	26	9045	7585	583
9	1085	910	202	27	9755	8180	606
10	1340	1120	224	28	10490	8800	628
11	1620	1355	246	29	11255	9435	650
12	1930	1615	269	30	12040	10100	673
13	2260	1895	291	31	12860	10780	696
14	2625	2200	314	32	13700	11490	718
15	3010	2525	337	33	14705	12220	741
16	3425	2870	359	34	15455	12960	763
17	3865	3245	381	35	16390	13745	785
18	4335	3635	404	36	17340	14540	808
19	4830	4050	426	37	18315	15360	830
20	5350	4490	449	38	19275	16200	853
21	5900	4950	471	39	20350	17065	875
22	6475	5430	493	40	21410	17950	896

Earth Level.

Total Inclined Pressure $= \dfrac{\cos\phi \, eh^2}{2(1+\sin\phi\sqrt{2})^2} = .1338\, eh^2$

Total Hor. Pressure $= 11.22\,h^2$ acting at depth $= \frac{2}{3}h$

Note: $e = 100$ lb. per cu. ft.; $h =$ Depth

GRAIN PRESSURES IN DEEP BINS

The pressures existing in full sized grain bins were investigated by Mr. J. A. Jamieson in 1903 and a very complete report of this investigation was published in the "Engineering News," March 10, 1904.

Grain in this country is usually stored in deep bins, and it has long been known that in these deep bins there is a head or depth of grain, which, were the grain a liquid, would produce enormous bursting pressures.

The actual pressures recorded by Mr. Jamieson permits us at once to draw a curve showing the ratio of observed grain pressure to a corresponding liquid pressure supposing the bin to be filled to the same depth with a liquid of the same weight per cubit foot as the grain. Such a curve is drawn on page 78. The ratio is shown as values of K for different values of $\frac{h}{b}$

It should be noted from Mr. Jamieson's tests that the pressures were somewhat increased when grain was running out of the bin and also that by tapping the sides of the model bins an increased pressure of 20 per cent. was obtained. The presence of moisture will also have considerable influence. For these reasons it is recommended that a factor of safety of six be used in designing grain bins.

Example—Let it be required to find the vertical and horizontal pressures at the bottom of a bin 10′0″ square and 40′0″ high.

$\frac{h}{b}=4.$

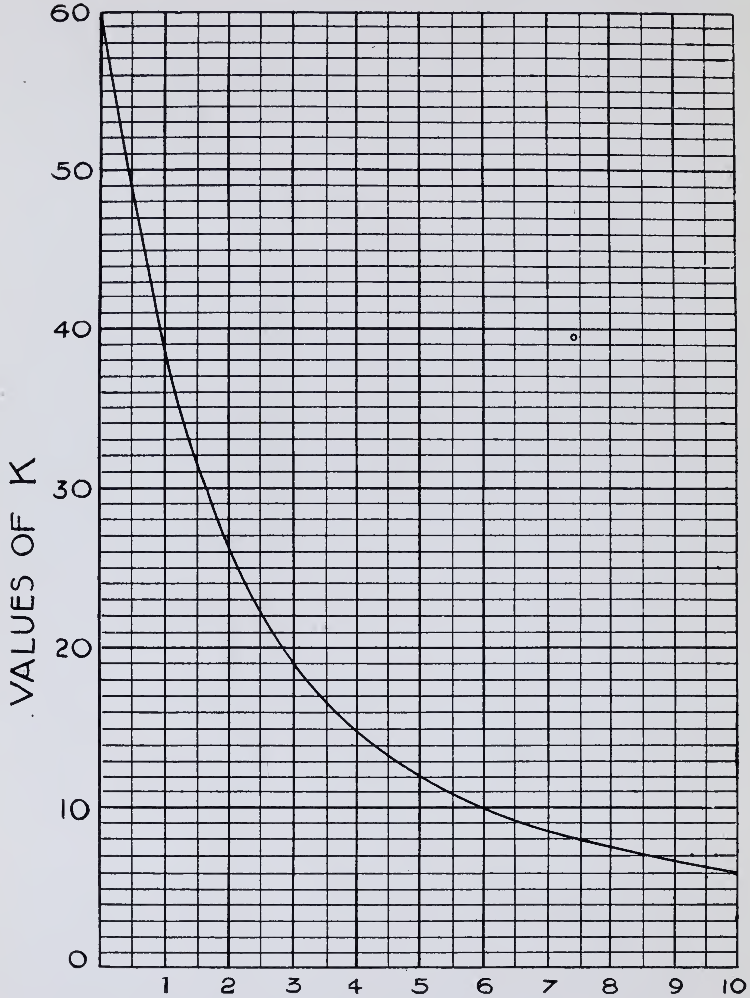
From the curve K=.149.

Side pressure=KWh=.149 x 50 x 40=298 pounds per square foot.

Bottom pressure=1.667 KWh=1.667 x side pressure=497 pounds per square foot.

Vertical load carried by side walls=200,000—(497 x 100)= 150,300 pounds.

WHEAT PRESSURES IN GRAIN BINS.



Values of $\frac{h}{b}$

Derived from experiments and formulae by J. A. Jamieson in Eng. News, 3-10-'04.

Angle of repose=28°. Coeff. of friction=41667. Lat. Pres. =0.6 Vert. Pres.

H=height or depth of grain. *b*=side of sq. bin or least width of rect. bin. *K*=Ratio of actual grain pressure to liquid pressure. *W*=weight of wheat=50 lbs. per cu. ft. Side pressure per sq. ft. =*KWh*. Bottom pressure at any depth =1.667 *KWh*.

Max. bottom pressure occurs when $\frac{h}{b} + 3.5$

Max. bottom pressure per sq. ft.=*Wb*.

ALLOWABLE FLOOR LOADS IN ACCORDANCE WITH THE BUILDING LAWS OF VARIOUS CITIES

LIVE LOADS FOR FLOORS IN DIFFERENT CLASSES OF BUILDINGS EXCLUSIVE OF THE WEIGHT OF THE MATERIALS OF CONSTRUCTION.	New York 1902	Chicago 1902	Philadelphia 1902	Boston 1902	San Francisco 1906
	Pounds per Square Foot				
Dwellings, Apartment Houses, Hotels, Tenement Houses or Lodging Houses	60	40	70	50	60
Office Buildings, 1st Floor	150	100	100	100	150
Office Buildings, Above 1st Floor	75	100	100	100	75
Schools or Places of Instruction	75			80	75
Stables or Carriage Houses	75	40* 100†			75
Buildings for Public Assembly	90	100	120	150	125
Buildings for ordinary stores, light manufacturing and light storage	120	100	120		120
Stores for Heavy Materials, Warehouses and Factories	150		150	250	250
Roofs—Pitch less than 20 degrees	50	25	30	25¶	50
Roofs—Pitch more than 20 degrees	30	25	30	25¶	30
Sidewalks	300				300
Public Buildings Except Schools				150	

* Stables less than 500 square feet in Area.

† Stables over 500 square feet in Area.

¶ Make proper allowance for wind at 30 lbs. per square foot hor.

DIGEST OF BUILDING LAWS GOVERNING REINFORCED CONCRETE.	New York	Cleveland	San Francisco	Buffalo	Toronto	Prussian Requirements
Ratio of Modulus of Elasticity of Steel to Concrete	12	15	15	12	12	
Tensile Stress in Steel	16000	16000	$\frac{1}{3}EL$	16000	16000	17000
Compressive Stress in Steel		12000			12000	
Shearing Stress in Steel	10000	10000	10000	10000	10000	
Extreme Fibre Stress on Concrete in Compression	500	* 500	500	500	500	$\frac{1}{5}U$
Concrete in Direct Compression	350	* 400	† 450	350	350	$\frac{1}{10}U$
Tensile Stress in Concrete	0	0	0	0	0	0
Shearing Stress in Concrete	50	50	75	50	50	64
Bending Moment in Beam Continuous	$\frac{1}{8}wl$	$\frac{1}{10}wl$	$\frac{1}{8}wl$	$\frac{1}{8}wl$	$\frac{1}{8}wl$	$\frac{1}{10}wl$
Bending Moment in Slabs Continuous	$\frac{1}{10}wl$	$\frac{1}{10}wl$	$\frac{1}{12}wl$	$\frac{1}{10}wl$	$\frac{1}{10}wl$	$\frac{1}{10}wl$
Bending Moment in Square Floor Panels	$\frac{1}{20}wl$	$\frac{1}{15}wl$	$\frac{1}{20}wl$	$\frac{1}{20}wl$	$\frac{1}{20}wl$	
Method of Calculation	S. L.	S. L.	S. L.	S. L.	S. L.	S. L.
T-Section Amount Allowed as part of Beam	10 b	6 b	5 t	10 b	5 b	$\frac{1}{3}l$
Columns–Maximum Ratio of Height to Width	12	16	15	16	12	18
Requirements of Tests	3 L	3 L	2 L	3 L	3 L	$2L+D$

NOTE:—S. L. = Straight Line Formula.
b = Breadth of Beam. t = Thickness of Slab.
w = Total Uniformly Distributed Load.
l = Length of Beam.
U = Ultimate. L = Live Load. D = Dead Load.
$E L$ = Elastic Limit.
† Hooped Columns—700 lb.
* 600 lb. If tests show factor of safety of 5 in ninety days.

REINFORCED CONCRETE BRIDGES

Reinforced concrete bridges are built of various types depending on the length of span, the amount of loading, and the requirements of the particular locations.

Flat slabs or plates spanning directly between the abutments without any supporting beams are used over small openings.

On longer spans the girder bridge with comparatively thin concrete floor slab is used. The cantilever bridge is a variation of the girder design in which the loads are carried by cantilever action over the support instead of as a simple beam.

The arch bridge is employed in long spans and is built in the form of a continuous section arch ring or merely a rib. Bridges of all these types have been built extensively for highway, electric car and railway traffic.

HIGHWAY BOX CULVERTS AND GIRDER BRIDGES

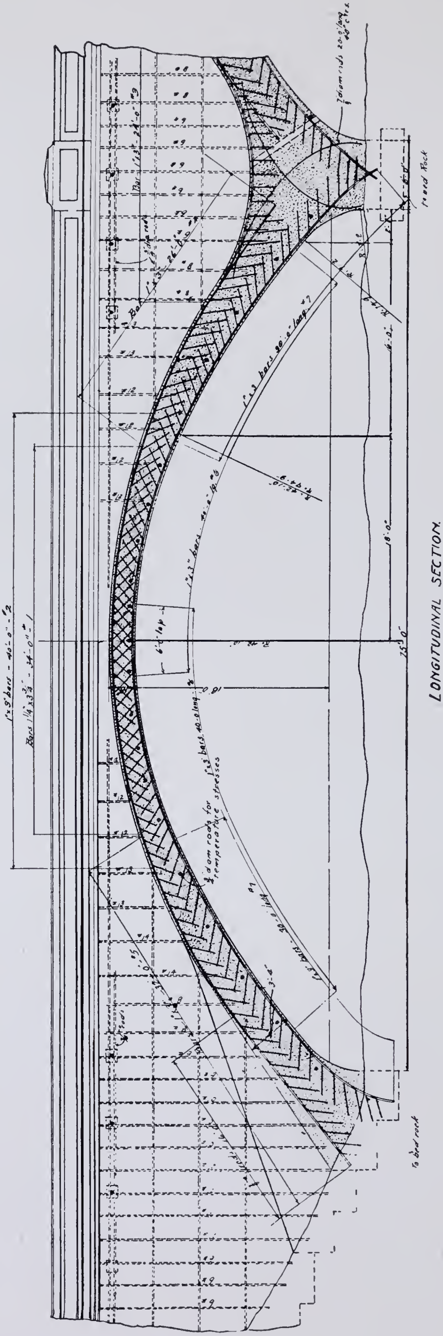
Flat slabs or culverts resting directly on the abutments are employed in spans of from 4 to 16 feet. The construction is simple and can be readily installed. Either of the two smaller sizes of Kahn trussed bars are used for reinforcement, and these bars are given a bearing of from 6 to 12 inches on the abutments. To take care of temperature and shrinkage stresses, small round rods are placed over and at right angles to the Kahn bars. On page 84 is given the tabulated design for various spans, computed for heavy highway loadings.

Girder bridges are most often used in spans of from 12 to 50 feet, although spans as great as 70 feet have been built in this way. The design usually consists of a reinforced slab supported by girders projecting underneath. Many bridges have been built, however, in which the girders are extended above the floor to form a hand rail on either side of the roadway. The floor slab would then span directly the width of the roadway between these girder rails.

The cantilever bridge is built for longer spans than the girder bridge. The secret of its great carrying capacity lies in its great depth at the abutment. At the center of the span, the girder is shallow giving ample headroom where required. The cantilever design should not be confused with an arch as there is no thrust and the reactions are all vertical.

The hand rail or balustrade for the concrete bridge can be built of reinforced concrete, ornamental iron, or plain gas pipe as desired.

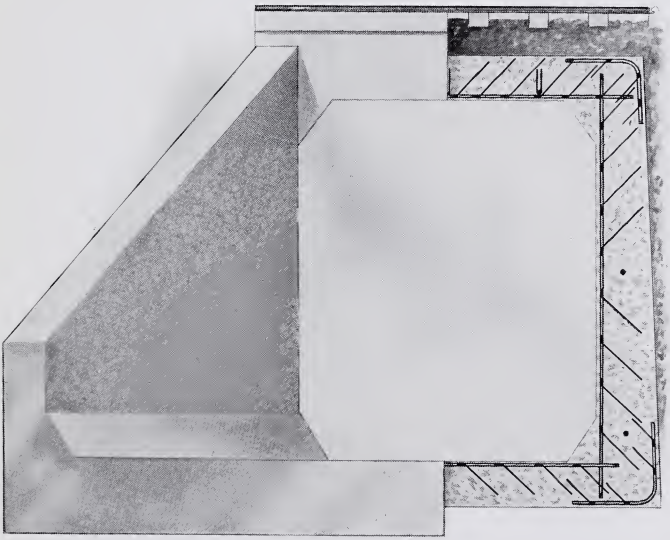
The experienced builder knows that there is no class of structure subjected to such severe conditions of loadings and



Showing the use of the Kahn Trussed Bar in the Charley Creek Viaduct, Wabash. Ind.
John Hilty, Engineer.

rough usuage as a bridge. Therefore, only the best concrete should be used and this concrete must be reinforced for the severe stresses coming upon it. The shearing stresses are very great due to heavy moving loads and shear reinforcement must be provided. This shear reinforcement should be rigidly attached to the main tension member. The adhesion of the concrete cannot be depended upon. The bond between the concrete and steel is completely destroyed by the repeated loading and unloading of the stress in the steel.* That the Kahn trussed bars are especially suited for such work is evident.

On page 85 is given a table for the design of girder bridges covering spans from 12 to 40′. The width of roadway is taken as 16′, the standard for the country highway bridge. Where the width of roadway varies from this, the design can be revised to meet the new conditions.



Showing Application of Kahn Trussed Bar
to Culvert Construction.

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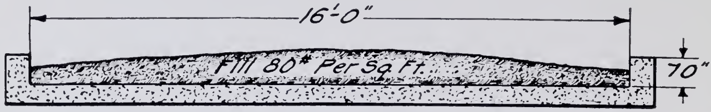
*See "The Fatigue of Concrete" by I. D. Van Ornum, M. A. S. C. E, Proceedings A. S. C. E. Dec. 1906.

Slab Highway Bridges or Culverts

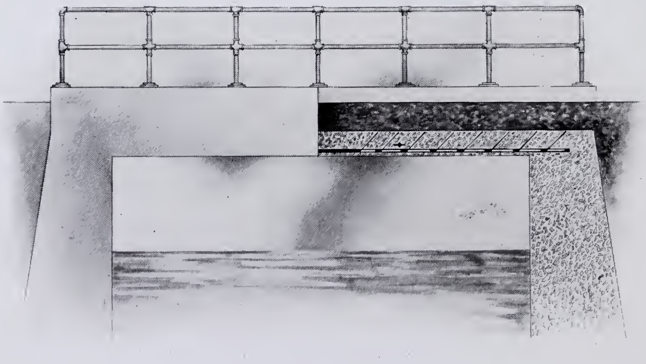


Cross Section

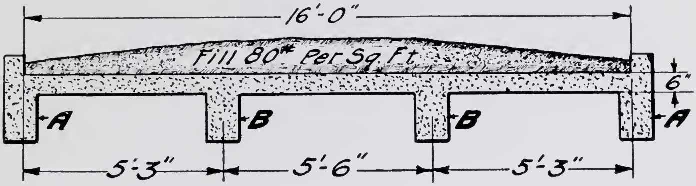
Live Load—15 Ton Roller or 100 pounds per sq. ft.

SPAN IN FEET	Thickness of Slab	KAHN BARS		CUP-BARS	
		SIZE	SPACING	SIZE	Spacing
4	6"	½"x1½"	12"	⅜"	24"
6	6"	½"x1½"	8"	⅜"	24"
8	7"	¾"x2 3/16"	12"	⅜"	24"
10	8"	¾"x2 3/16"	10"	⅜"	24"
12	9"	¾"x2 3/16"	11"	⅜"	24"
14	10"	¾"x2 3/16"	9"	⅜"	24"

Cup-Bars are placed over and at right angles to Kahn Bars.



GIRDER HIGHWAY BRIDGES.



Live Load—15 Ton Roller or 100 pounds per sq. ft.

SPAN IN FT.	BEAM A					BEAM B				
	SIZE	KAHN BARS				SIZE	KAHN BARS			
		STANDARD SHEARED		CENTER SHEARED			STANDARD SHEARED		CENTER SHEARED	
		No.	SIZE	No.	SIZE		No.	SIZE	No.	SIZE
12	10"x16"	2	¾"x2 3/16"	1	¾"x2 3/16"	12"x16"	2	1"x3"	1	¾"x2 3/16"
14	10"x16"	2	¾"x2 3/16"	*1	1"x3"	12"x16"	2	1"x3"	1	1"x3"
16	10"x18"	2	1"x3"	1	¾"x2 3/16"	12"x18"	2	1"x3"	*1	1¾"x2¾"
18	12"x18"	2	1"x3"	1	¾"x2 3/16"	14"x18"	2	1¾"x2¾"	1	1"x3"
20	12"x20"	2	1"x3"	1	1"x3"	14"x20"	2	1¾"x2¾"	1	1¾"x2¾"
22	12"x22"	2	1"x3"	1	1"x3"	14"x22"	2	1¾"x2¾"	1	1¾"x2¾"
24	12"x22"	2	1¾"x2¾"	1	¾"x2 3/16"	14"x22"	2	2"x3½"	1	1"x3"
26	12"x24"	2	1¾"x2¾"	1	1"x3"	14"x24"	2	2"x3½"	1	1"x3"
28	12"x26"	2	1¾"x2¾"	1	1"x3"	14"x26"	2	2"x3½"	1	2"x3½"
30	12"x28"	2	1¾"x2¾"	1	¾"x2 3/16"	16"x28"	2	2"x3½"	1	2"x3½"
32	12"x30"	2	1¾"x2¾"	1	¾"x2 3/16"	16"x30"	2	2"x3¾"	1	2"x3½"
34	14"x30"	2	2"x3½"	1	1"x3"	16"x30"	3	2"x3½"	2	¾"x2 3/16"
36	14"x32"	2	2"x3½"	1	1"x3"	16"x32"	3	2"x3½"	3	¾"x2 3/16"
38	14"x34"	2	.2"x3½"	1	1"x3"	18"x34"	3	2"x3½"	2	1"x3"
40	14"x36"	2	2"x3½"	1	¾"x2 3/16"	18"x36"	3	2"x3½"	2	¾"x2 3/16"

*Bars full length.

FLOOR SLAB.—6" thick, reinforced with ½"x1½" Kahn Bars, spaced 12" c. to c. and ⅜" Cup-Bars spaced 16" c. to c.

RAILROAD BOX CULVERTS

Box culverts for railroad work are similar to highway culverts except that they must be built much heavier to carry the greatly increased loading coming upon them. The side walls are usually reinforced to withstand the earth pressure due to dead and live loads. If sufficient abutment is provided for this wall at the base, it may be designed as a simple slab supported at the top and bottom. In this way the walls can be greatly reduced in thickness over what would be required for a plain concrete wall.

The footings for culverts are determined by local conditions. It will often be found necessary to carry an inverted slab continuous between the side walls in order to provide ample bearing for the heavy loads coming on these foundations. Under such circumstances this floor slab would be of the same strength as the cover slab, with the bars inverted in the top of the slab.

The wing walls of culverts can be built of reinforced concrete, their design being the same as for an ordinary retaining wall.

In the calculation of moments in culverts, a live load is assumed of 50,000 pounds on axles, 5 feet centers, 10,000 pounds per foot of track. This load may be taken as distributed uniformly over ties 8 feet long. The manner in which this live load will be distributed when it reaches the culvert cover will depend on the nature of the overlying material. In this discussion it will be assumed that the line of zero stress in the enbankment due to live load is much more nearly vertical than the ordinary angle of repose of the material and it will be taken to follow a slope of ½ to 1.

For a fill of less than 2 feet, the impact allowance should be 100 per cent.; between 2 feet and 4 feet, 75 per cent.; above four feet an allowance of 50 per cent. will be made.

Let P_L = unit pressure on cover per sq. ft. due to live load.

P_D = unit pressure on cover per sq. ft. due to dead load.

$$P = P_L + P_D$$

Total load per lineal foot = 10,000 pounds, adding 50 per cent. for impact. = 15,000 pounds.

$$15{,}000 = P_L\left(8 + \frac{h}{2}\right) \text{ or } P_L = \frac{30{,}000}{h + 16}$$

$$P_D = 100\,h,$$

$$p = \frac{30{,}000}{h + 16} + 100\,h = \text{total superimposed load per sq. ft. on cover.}$$

COVERS FOR RAILWAY BOX CULVERTS

Cooper's E 50 Loading

SPAN IN FEET	Depth of Fill in Feet	Thickness of Slab in Inches	Size of Kahn Bars	Spacing in Inches	SPAN IN FEET	Depth of Fill in Feet	Thickness of Slab in Inches	Size of Kahn Bars	Spacing in Inches
4	10	8	¾″x2 ″	10.0	12	10	19	1″x3″	8.5
	15	8	"	9.0		15	20	"	7.5
	20	9	"	9.5		20	22	"	7.5
	25	9	"	8.0		25	23	1¾″x2¾″	10.0
	30	10	"	8.0		30	24	"	9.0
	35	10	"	7.5		35	26	"	9.0
	40	11	"	7.5		40	27	"	8.0
6	10	11	¾″x2″	10.0	14	10	21	1¾″x2¾″	10.0
	15	11	"	8.5		15	23	"	9.5
	20	12	"	8.5		20	25	"	9.0
	25	13	"	8.0		25	27	2″x3½″	12.0
	30	13	"	7.0		30	28	"	12.0
	35	14	"	7.0		35	29	"	11.0
	40	15	"	6.5		40	32	"	11.0
8	10	13	¾″x2″	7.5	16	10	25	2″x3½″	13.5
	15	14	"	6.5		15	26	"	12.5
	20	15	1″x3″	11.0		20	28	"	11.5
	25	16	"	10.5		25	30	"	11.0
	30	17	"	10.0		30	32	"	10.5
	35	18	1¾″x2¾″	13.0		35	33	"	9.5
	40	19	"	12.0		40	36	"	9.5
10	10	16	1″x3″	10.0	18	10	28	2″x3½″	12.0
	15	17	"	9.0		15	30	"	11.0
	20	19	"	9.0		20	31	"	10.0
	25	20	"	8.5		25	33	"	9.5
	30	21	"	8.0		30	35	"	9.0
	35	22	1¾″x2¾″	10.5		35	37	"	8.5
	40	23	"	10.0		40	39	"	8.0

On page 87 will be found table of design of culvert tops of various spans and depth of fill, computed on the above basis. The design for side walls are determined by local conditions of soil, drainage, etc., and for this reason cannot be conveniently tabulated. When a floor slab is used continuous between side walls, its design is merely the invert of the culvert cover.

ARCH BRIDGES

The arch bridge of reinforced concrete is built either in the form of a continuous section arch ring, or as an arch rib. The reinforcement for arches is placed in two layers, one near the intrados, the other near the extrados with the diagonals interlacing. Attention is called to the perfect lattice girder effect produced by the interlacing of the diagonals, making the entire structure act as a monolith, under any condition of loading. The reinforcement being curved into an arch form, its first tendency when under stress is to straighten, and this will occur unless it is restrained from doing so by rigidly attached diagonals extending well into the concrete. This makes the Kahn Trussed Bar especially adaptable for work of this kind.

The continuous section arch has the same thickness of rib throughout its width. The thickness is a minimum at the center increasing in thickness to a maximum at the abutments. It is frequently possible and advantageous to build these abutments hollow instead of a solid block of concrete. The hollow abutment consists of a series of buttresses carried down to a good foundation and usually connected at the base by a thick reinforced slab. The earth fill between the buttresses tends to insure stability. As the strength of the arch is based on the immobility of its abutments, these abutments must be carefully designed and carried to a foundation of unquestioned value or founded on piles.

Usually the earth fill is built directly on the arch ring. Occasionally in long spans, a complete superstructure of reinforced concrete columns, girders and slabs is built on the arch ring to carry the roadway. The advantage of this design is the greatly reduced loading to be carried and the consequent reduction in the thickness of the arch ring. This is an important consideration in long span work.

The arch rib design consisting of a series of ribs of reinforced concrete is especially adapted for long span work and is usually built supporting a reinforced concrete superstructure. Otherwise these ribs may consist of a series of spandrel sections

with reinforced beams or slabs, spanning between the tops of them, such as the Lake Park Bridge and the Nelson Street Viaduct.

There is no doubt that the best guides to the design of arch bridges are existing structures that have proven satisfactory. The use of empirical formulae giving results that agree with current practice is therefore justifiable.

One method of designing an arch giving approximate results, is to determine the crown thickness (C) by the use of an empirical formula: make the thickness of the ring at the quarter points equal from 1¼C to 1½C, and place steel near both intrados and extrados. The total net section of which is equal to .¾% of the area of the crown section of the arch ring.

The following formula for crown thickness proposed by F. F. Weld, C. E., in Engineering Record, November 4th, 1905, based on a study of many existing arches and original designs is inserted for the use of those who do not care to make a more thorough investigation of the proposed arch. It will also be found useful in determining a trial arch ring for the more rigorous methods.

$$C=\sqrt{S}+\frac{S}{10}+\frac{L}{200}+\frac{F}{400}$$

C=Crown thickness in inches,
S=Clear span in feet,
L=Live load per square foot,
F=Weight of fill at crown per sq. ft.

Among the more elaborate methods for determining the stresses in an arch without hinges may be mentioned the graphical, of which an excellent discussion is given in Prof. Cain's "Steel Concrete Arches & Domes," and also in a slightly modified form, in "Reinforced Concrete," by Chas. F. Marsh. The analytical method which follows is condensed from the chapter on "Parabolic Ribs with Fixed Ends," in Prof. Chas. E. Greene's "Trusses and Arches," Part III.

TYPICAL HIGHWAY ARCH BRIDGES

Rise = $\frac{1}{10}$ Span

CLEAR SPAN IN FEET	CROWN Thickness	STEEL IN INTRADOS AND EXTRADOS		Concrete in Arch Cu. Feet	Concrete in Abutments Cu. Feet
		Kahn Bars	Spacing		
20	8″	¾″x2$\frac{3}{16}$″	16″ c. to c.	700	2000
30	10″	¾″x2$\frac{3}{16}$″	14″ "	1050	2800
40	12″	¾″x2$\frac{3}{16}$″	12″ "	1600	3400
50	13½″	1″x3″	18 "	2250	4000
60	15″	1″x3″	16″ "	3000	5000
70	16½″	1″x3″	15″ "	3800	6000
80	18″	1″x3″	14″ "	4800	7000
90	20″	1″x3″	13″ "	5800	8000
100	22″	1″x3″	12″ "	6900	9000
110	24″	1″x3″	11″ "	8200	10000
120	26″	1″x3″	10″ "	9500	11000

Note:—This table is designed for low arch bridges with a rise of 1-10th of the span, a live load of 150 lbs. per square foot and a fill of not less than 12 inches.

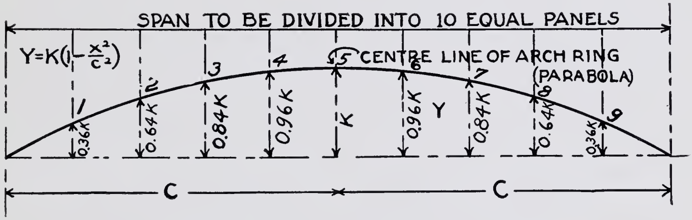
Width of roadway—16′0″ in the clear for all spans.

Spandrel walls to be reinforced with ¾″x2$\frac{3}{16}$″ Kahn Bars spaced 2′0″ c. to c.

Amounts of concrete in abutments are rough approximations as local conditions govern.

DESIGNS OF PARABOLIC ARCHES WITHOUT HINGES.

Let the span be divided into ten equal panels and points of division numbered from one to nine.



w=load in pounds at point under consideration.

c=one-half span (in feet),

k=rise of arch (in feet),

m=ratio between load (w) and bending moment, taken from table,

M=bending moment due to load at point under consideration $= m\ c\ w$.

h=ratio between load and thrust produced, taken from table,

H=thrust produced by load under consideration$=h\frac{c}{k}w$

—indicates tension in extrados,

+ indicates tension in intradoes.

In order to make plain this method of calculation, and the use of the table let it be assumed that it is desired to design a highway bridge having a clear span of 60 feet and a rise of 6 feet to carry a live load of 100 pounds per sq. ft.

The weight of the fill at the crown is assumed to be 200 pounds per sq. ft. Substituting these values in the empirical formula for crown thickness, gives 14.7″.

ARCHES—TABLE No. 1

Parabolic Rib Fixed At Ends. **Values Of "*m*" At Points.**

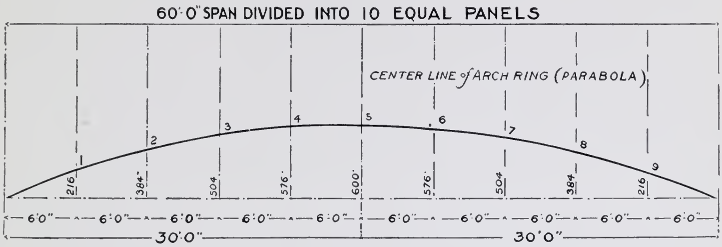
Points	POSITION OF LOAD "*W*" 9	8	7	6	5	4	3	2	1
0	+.022	+.064	+.095	+.096	+.062	0	—.073	—.128	—.121
1	+.006	+.016	+.019	+.011	—.006	—.026	—.036	—.018	+.051
2	—.005	—.017	—.031	—.040	—.037	—.017	+.028	+.107	+.028
3	—.012	—.035	—.054	—.056	—.031	+.026	+.119	+.048	+.011
4	—.013	—.037	—.050	—.037	+.012	+.104	+.036	+.004	—.002
5	—.010	—.024	—.020	+.016	+.094	+.016	—.020	—.024	—.010
6	—.002	+.004	+.036	+.104	+.012	—.037	—.050	—.037	—.013
7	+.011	+.048	+.119	+.026	—.031	—.056	—.054	—.035	—.012
8	+.028	+.107	+.028	—.017	—.037	—.040	—.031	—.017	—.005
9	+.051	—.018	—.036	—.026	—.006	+.011	+.019	+.016	+.006
10	—.121	—.128	—.073	0	+.062	+.096	+.095	+.064	+.022

VALUES OF "*h*" FOR
VARIOUS POSITIONS OF LOAD "*W*"

Points	9	8	7	6	5	4	3	2	1
	.061	.192	.331	.432	.469	.432	.331	.192	.061

From Prof. C. E. Greene's "Trusses and Arches." Part III.

Lay out the center line of the proposed arch for the given span and rise, divide it into ten equal parts, numbering them as shown in the figure.



In arch design it is customary to figure the loads and stresses for a section of the bridge one foot wide, for, having determined the necessary section on this basis, the bridge may be made as desired. This of course does not apply to bridges having arch ribs. Here the loads and stresses are determined for each rib.

Compute the loads that would come at each of these points for an arch ring one foot wide if the weight of the structure and fill were concentrated at them, and tabulate as in table No. 2.

ARCHES—TABLE No. 2

Point	Weight of Arch Ring	Weigh of Fill	Total
1	1800	6000	7800
2	1600	2400	4000
3	1400	1600	3000
4	1300	1300	2600
5	1200	1200	2400
6	1300	1300	2600
7	1400	1600	3000
8	1600	2400	4000
9	1800	6000	7800

To find the bending moment at any point, as No. 7 proceed as in table No. 3.

(*Continued on Page 95.*)

TABLE No. 3

Moments and Thrusts in 60 Ft. Highway Arch—Section One Foot Wide.

1	2	3	4	5	6	7	8	9	10	11	12	13
Points	c	k	Values of "*m*" Table 1	Dead Loads		Live Load On Right		Live Load On Left		Values of "*h*" Table No. 1	Total W	Horizontal Thrust $H=h\frac{c}{k}W$
				W_1	$M= m.c.W_1$	W_2	$M= m.c.W_2$	W_2	$M= m.c.W_2$			
9	30	6	+.011	7800	+2570	600	+200			.061	8400	2560
8	30	6	+.048	4000	+5760	600	+860			.192	4600	4420
7	30	6	+.119	3000	+10710	600	+2140			.331	3600	5960
6	30	6	+.026	2600	+2170	600	+470			.432	3200	6910
5	30	6	—.031	2400	—2230	300	—280	300	—280	.469	3000	7030
4	30	6	—.056	2600	—4410			600	—1010	.432	3200	6910
3	30	6	—.054	3000	—4860			600	—970	.331	3600	5960
2	30	6	—.035	4000	—4200			600	—630	.192	4600	4420
1	30	6	—.012	7800	—2800			600	—220	.061	8400	2560
					+2710		+3390		—3110			46730#
							+2710		+2710			
							+6100#		— 400#			

Note:—Maximum positive moment at point No. 7= 6100 ft. lbs.

Maximum negative moment at point No. 7= —400 ft. lbs.

Maximum horizontal thrust of section considered=46730 lbs.

In column No. 1 are the points in order. Column No. 4 contains the factors "m" found opposite No. 7 of table No. 1. The half span c and weights W, from table No. 2 are given in columns Nos. 2 and 5 opposite their respective points. The bending moment in foot pounds is given in column No. 6. The algebraic sum of these moments gives the bending moment at point 7 for the unloaded arch.

The moments due to the live load are computed in the same way. If a street car loading is specified it may be reduced to an equivalent uniformly distributed load by means of the equivalent load diagram.

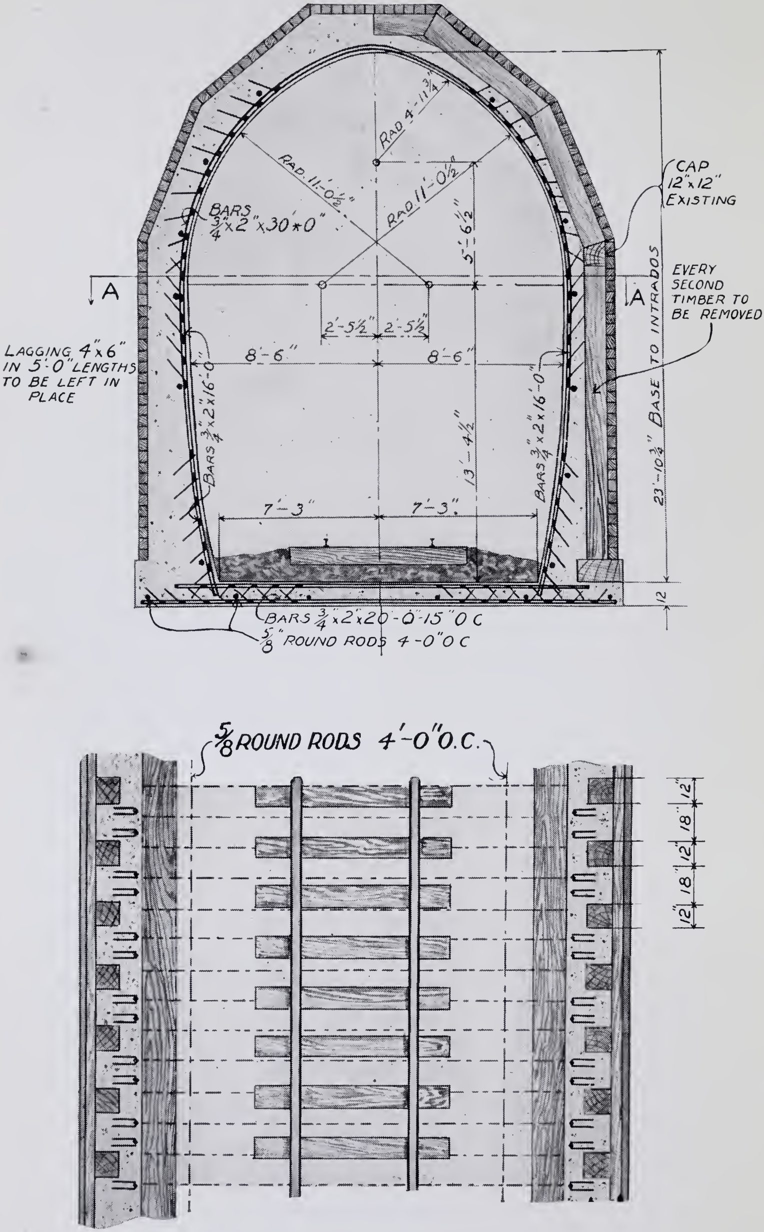
The live load is usually assumed to extend from one abutment to the center of the span, but may be placed in such positions as would give the greatest stresses at the points under consideration if such loadings are likely to occur when the bridge is actually in use. For example, by an inspection of the signs of the coefficients in table No. 1 it will be seen that for the maximum negative moments at point 7 the live load should not extend quite to the center of the span.

The assumed live load of 100 pounds per sq. ft. extending from the right abutment to the center of the span gives a load of 600 pounds concentrated at each of the points 9, 8, 7 and 6 and 300 pounds at 5. These weights are entered in column 7 of table No. 3, "m" and "c", remaining the same; column 8 gives the resulting moments. This sum added to the moment of the unloaded arches gives a total positive moment due to both dead and live loads at this point.

The maximum negative moment is found by placing the live loads upon the other half of the bridge, as in columns 9 and 10, and taking the algebraic sum of the moments due to both live and dead loads.

The necessary amount of steel reinforcement may be found by the formula $R\,M$—.86 a. d. s., where—s—is allowed stress in steel, a—area of steel; d—distance from center of steel to opposite surface of arch rib, and $R\,M$—Resisting moment of section which must be at least equal to the bending moment produced by the loads. The steel is assumed to take only tension and the concrete only compression. Allowance should be made for the fact that there is no tension in the arch rib unless the line of action of the resultant thrust passes outside of the middle third of the section; in other words, unless $M \div H > d \div 6$.

The horizontal thrust is a maximum when the arch is fully loaded and is found by means of the factors given at the foot of table No. 1. The results are tabulated in the last



Tunnel Missouri Pacific Railway

three columns of table No. 3. The sum gives the maximum horizontal thrust exerted upon the abutments by the loaded arch. This combined graphically with the dead weight of the half span and fill gives a resultant thrust which is in turn combined with the weight of the abutment and superimposed earth. This latter resultant gives the amount and direction of the thrust of the abutment upon its foundation. In order that there may be no overturning tendency this resultant should pass within the middle third of the base.

If the assumed abutment does not meet these conditions a new length of base should be assumed and the new position of the resultant determined.

In case the arch ring is not parabolic in form, but does not depart widely from the parabola, this method of computation may be employed by determining a new span for the arch, which with the given rise will give the same area between the springing line and the neutral surface curve as would be included between the same elements if the curve was a parabola, or recourse may be had to one of the graphical methods where the description of the curve is of less consequence.

NOTES REGARDING ERECTION

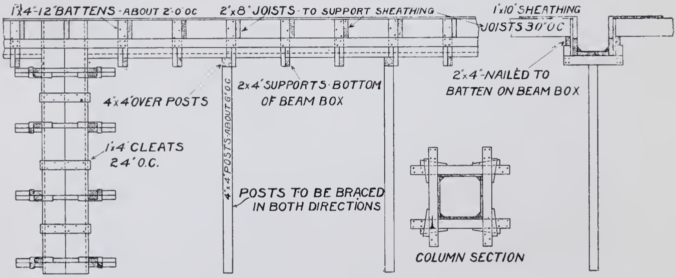
[Note.—The following is a brief outline of construction methods. For detailed information see "Instructions to Superintendents", and "Specifications for Reinforced Concrete Work", two booklets published by The Trussed Concrete Steel Co.]

The erection of a reinforced structure is similar to the making of a casting in a large foundry. Forms or patterns are built to correspond exactly with the lines of the finished work, the reinforcing steel is set in place, and the concrete is poured into the forms. The whole structure is thus built as a monolith and moulded into the finished form. The concrete is allowed to set a requisite length of time, the forms are removed, and the building stands complete,—a structure carved, as it were, out of solid rock.

It is thus seen that the erection work consists primarily of four distinct operations. 1st. The erection of the centering or false work. 2nd. The placing of the reinforcing steel. 3rd. The mixing and placing of the concrete, and 4th., the removal of the centering.

ERECTION OF CENTERING

As the forms represent the mould from which the finished structure is made, great care is used to make these exact and true to line. They are built rigid and thoroughly braced so as to bear the weight of the plastic concrete without deflection. In order to give a smooth



finished surface planed boards are used, and corners of columns and beam boxes are chamfered. All joints are set closely together to make the forms fairly water tight.

PLACING STEEL

The steel is set accurately in place in accordance with detailed drawings prepared for that purpose and these drawings are followed explicitly. The Engineering Department of The Trussed Concrete Steel Co. prepares such drawings for work in which the Kahn

Trussed Bars are used, when desired by, and without charge to the client.

MIXING AND PLACING CONCRETE

Only the best materials are used for the concrete, and these are thoroughly mixed of the proper proportions. A rather wet mixture is used. The concrete is poured into the forms and is laid continuously over the entire floor area. It is placed carefully around the steel work, so as not to disturb the location of the bars and to thoroughly cover them at all points. The concrete is puddled in the form so as to allow no voids to occur.

The hardening of concrete is not a "Drying out" process, as some suppose, but is a chemical action caused by the addition of the water to the cement. The concrete takes its "Initial set" in a short time and therefore should be deposited in place as quickly after mixing as possible.

Concrete work is often carried on in the winter months and will freeze if precautions are not taken. The freezing retards the setting of the concrete and often completely ruins it. It is usually best to remove any concrete known to have been frozen. Simple precautions can be taken to prevent such freezing such as heating the materials, adding salt to the water (less than a 10 per cent. solution), keeping the building heated by charcoal grates and covering the concrete after being laid with some good insulating material such as cement bags, straw, manure, etc.

REMOVAL OF FORMS

After the concrete has *thoroughly* set and hardened, the forms are carefully taken down. This is done gradually and evenly so as to cause no undue shocks on the concrete work. The length of time necessary to leave the forms in place depends very largely on the atmospheric conditions, the season of the year, the thickness of the concrete work, and the kind of cement used. With the removal of the forms the structural portion of the building is complete and ready for use. The concrete, however, will continue to grow harder and stronger every day.

FINISH ON CONCRETE WORK

The most common finish for floors is the ordinary cement finish. This is a cement mortar composed of one part Portland cement and two parts clean sharp sand. It is preferably laid at the same time as the main body of the concrete work in order to procure adhesion to the same. If for any reason this cannot be done, the old concrete should be thoroughly cleaned before the finish is laid, and the finish should be made at least one inch in thickness. A less thickness will crack off. The cement finish should be

marked off in squares, the line of the marking being so arranged as to bring them over all beams and girders.

Where finished wood floors are laid on concrete, bevelled wood sleepers are used as nailing strips. These sleepers are about 2x3″ in size, and are placed usually 16″ on centers. Between the sleepers a filling of weak cinder concrete is used to hold them in place.

Marble, tile, mosaic and similar floors are laid on concrete construction by imbedding them in a cement mortar.

Where a cement finish is desired on concrete walls, the finish should be placed while the wall is being built. The rough concrete is spaded back from the forms and the rich mortar placed in front of it. A cement finish plastered on concrete after the wall is built will usually crack and not give the best results. After the forms are removed the concrete should be rubbed smooth and given a coat of cement wash mixed and applied as a paint.

There are many other ways of obtaining pleasing appearances to finished concrete work, such as bush hammering, pebble dash, Quimby process and a large variety of patented processes, all of which have been used with more or less success.

WATERPROOFING

For all ordinary purposes the use of a rich wet mixture with a cement finish will be as waterproof as necessary. In some cases, however, special provision must be made. The use of asphalt and tar and felt combinations are old methods and always give good results.

A number of methods to make concrete waterproof in itself have been used. The following method has been employed in some very large work and with good results:

The "Waterproof mortar" is made of 1 part Portland Cement and two parts of sand. Add ¾ pound pulverized alum, for each cu. ft. of sand and mix dry. Then add the proper quantity of water in which has been dissolved ¾ pound soft soap per gallon of water and mix thoroughly.

This mortar is applied as a plaster 1″ in thickness and is also useful in preventing efflorescence.

Besides this there are a large number of waterproof cements, compounds and patented processes upon the market, which give more or less satisfactory results.

BRIEF SPECIFICATIONS OF MATERIALS FOR REINFORCED CONCRETE WORK*

REINFORCING STEEL

Steel for reinforced concrete shall be made by the Open Hearth process. This steel shall have an ultimate tensile strength of from 60,000 to 70,000 pounds per sq. ft. and an elastic limit of at least half that amount, with an elongation of at least 20 per cent. A bar shall bend cold through an angle of 180 degrees and close down on itself without cracking. High carbon steel or steel with an elastic limit greater than 45,000 pounds per sq. in. shall not be used in reinforced concrete work.

Reinforcing steel shall provide for shearing stresses. These shear members shall be rigidly attached to the main tension member and preferably be part of the same bar..

CEMENT

Cement shall be of such requirements as to satisfy the standard specifications for cement adopted by The American Society for Testing materials Nov. 14th, '04.

SAND, STONE, GRAVEL

Sand shall be clean, and sharp, and not contain over 3 per cent. loam. Broken stone and gravel shall be hard and close grained and free from dust and dirt. They shall be of such size as to pass through a ring one inch in diameter.

PROPORTIONS

Concrete for beams and slabs shall be proportioned of one part Portland cement, two parts sand, 4 parts broken stone or gravel, concrete for columns shall be a 1 :1½ :3 mixture.

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*For detailed requirements see "Specifications for Reinforced Concrete Work," published by the Trussed Concrete Steel Co.

QUANTITIES OF MATERIAL FOR ONE CUBIC YARD OF RAMMED PLAIN AND REINFORCED",

Proportions by Parts			Proportions by Volume			Volume of Mortar in Terms of Percentage of Volume of Stone	PERCENT 50% Broken Stone Screened to Uniform Size		
Cement	Sand	Stone	Packed Cement	Loose Sand	Loose Stone		Cement	Sand	Stone
			Bbl.	Cu. Ft.	Cu. Ft.	Per Cent.	Bbl.	Cu. Yd.	Cu. Yd.
1	1	1.5	1	3.8	5.7	99	3.19	0.45	0.67
1	1	2	1	3.8	7.6	75	2.85	0.40	0.80
1	1	2.5	1	3.8	9.5	61	2.57	0.36	0.90
1	1	3	1	3.8	11.4	51	2.34	0.33	0.99
1	1.5	2	1	5.7	7.6	93	2.49	0.53	0.70
1	1.5	2.5	1	5.7	9.5	76	2.27	0.48	0.80
1	1.5	3	1	5.7	11.4	64	2.09	0.44	0.88
1	1.5	3.5	1	5.7	13.3	55	1.94	0.41	0.96
1	1.5	4	1	5.7	15.2	49	1.80	0.38	1.01
1	1.5	4.5	1	5.7	17.1	44	1.69	0.36	1.07
1	1.5	5	1	5.7	19.0	40	1.59	0.34	1.12
1	2	3	1	7.6	11.4	75	1.89	0.53	0.80
1	2	3.5	1	7.6	13.3	65	1.76	0.49	0.87
1	2	4	1	7.6	15.2	57	1.65	0.46	0.93
1	2	4.5	1	7.6	17.1	51	1.55	0.44	0.98
1	2	5	1	7.6	19.0	47	1.47	0.41	1.03
1	2	5.5	1	7.6	20.9	43	1.39	0.39	1.08
1	2	6	1	7.6	22.8	40	1.32	0.37	1.11
1	2.5	3	1	9.5	11.4	87	1.72	0.61	0.73
1	2.5	3.5	1	9.5	13.3	75	1.62	0.57	0.80
1	2.5	4	1	9.5	15.2	66	1.52	0.54	0.86
1	2.5	4.5	1	9.5	17.1	60	1.44	0.51	0.91
1	2.5	5	1	9.5	19.0	54	1.37	0.48	0.96
1	2.5	5.5	1	9.5	20.9	49	1.30	0.46	1.01
1	2.5	6	1	9.5	22.8	46	1.24	0.44	1.05
1	2.5	6.5	1	9.5	24.7	42	1.18	0.42	1.08
1	2.5	7	1	9.5	26.6	40	1.13	0.40	1.11
1	3	4	1	11.4	15.2	76	1.42	0.60	0.80
1	3	4.5	1	11.4	17.1	68	1.34	0.57	0.85
1	3	5	1	11.4	19.0	61	1.28	0.54	0.90
1	3	5.5	1	11.4	20.9	56	1.22	0.52	0.94
1	3	6	1	11.4	22.8	52	1.16	0.49	0.98
1	3	6.5	1	11.4	24.7	48	1.12	0.47	1.02

CONCRETE BASED ON A BBL. OF 3.8 CU. FT. FROM "CONCRETE, TAYLOR & THOMPSON.

AGE OF VOIDS IN BROKEN STONE OR GRAVEL											
45% Average Conditions			40% Gravel			30% Scientifically Graded Mixtures			20%		
Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone
Bbl.	Cu. Yd.	Cu. Yd.	Bbl.	Cu. Yd.	Cu. Yd.	Bbl.	Cu. Yd.	Cu. Yd.	Bbl.	Cu. Yd.	Cu. Yd.
3.08	0.43	0.65	2.97	0.42	0.63	2.78	0.39	0.59	2.62	0.37	0.55
2.73	0.38	0.77	2.62	0.37	0.74	2.43	0.34	0.68	2.26	0.32	0.64
2.45	0.34	0.86	2.34	0.33	0.82	2.15	0.30	0.76	1.99	0.28	0.70
2.22	0.31	0.94	2.12	0.30	0.90	1.93	0.27	0.82	1.77	0.25	0.75
2.40	0.51	0.68	2.31	0.49	0.65	2.16	0.46	0.61	2.03	0.43	0.57
2.18	0.46	0.77	2.09	0.44	0.74	1.94	0.41	0.68	1.80	0.38	0.63
2.00	0.42	0.84	1.91	0.40	0.81	1.76	0.37	0.74	1.63	0.34	0.64
1.84	0.39	0.91	1.76	0.37	0.87	1.61	0.34	0.79	1.48	0.31	0.73
1.71	0.36	0.96	1.63	0.34	0.92	1.48	0.31	0.83	1.36	0.29	0.77
1.60	0.34	1.01	1.51	0.32	0.96	1.37	0.29	0.87	1.25	0.26	0.79
1.50	0.32	1.06	1.42	0.30	1.00	1.28	0.27	0.90	1.17	0.25	0.82
1.81	0.51	0.76	1.74	0.49	0.74	1.61	0.45	0.68	1.50	0.42	0.63
1.68	0.47	0.83	1.61	0.45	0.79	1.48	0.42	0.73	1.38	0.39	0.68
1.57	0.44	0.88	1.50	0.42	0.84	1.38	0.39	0.78	1.27	0.36	0.72
1.48	0.42	0.94	1.41	0.40	0.89	1.28	0.36	0.81	1.18	0.33	0.75
1.39	0.39	0.98	1.32	0.37	0.93	1.20	0.34	0.84	1.10	0.31	0.77
1.31	0.37	1.01	1.25	0.35	0.97	1.13	0.32	0.87	1.03	0.29	0.80
1.25	0.35	1.06	1.18	0.33	1.00	1.06	0.30	0.89	0.97	0.27	0.82
1.66	0.58	0.70	1.60	0.56	0.68	1.49	0.52	0.63	1.40	0.49	0.59
1.55	0.55	0.76	1.49	0.52	0.73	1.38	0.49	0.68	1.29	0.45	0.64
1.46	0.51	0.82	1.40	0.49	0.79	1.29	0.45	0.73	1.19	0.42	0.67
1.37	0.48	0.87	1.31	0.46	0.83	1.20	0.42	0.76	1.11	0.39	0.70
1.30	0.46	0.92	1.24	0.44	0.87	1.13	0.40	0.80	1.04	0.37	0.73
1.23	0.44	0.95	1.17	0.41	0.91	1.07	0.38	0.83	0.98	0.34	0.76
1.17	0.41	0.99	1.11	0.39	0.94	1.01	0.36	0.85	0.92	0.32	0.78
1.12	0.39	1.02	1.06	0.37	0.97	0.96	0.34	0.88	0.88	0.31	0.80
1.07	0.37	1.05	1.01	0.36	0.99	0.91	0.32	0.90	0.83	0.29	0.82
1.36	0.36	0.77	1.30	0.55	0.73	1.21	0.51	0.68	1.12	0.47	0.63
1.28	0.55	0.81	1.23	0.52	0.78	1.13	0.48	0.72	1.05	0.44	0.66
1.22	0.52	0.86	1.17	0.49	0.82	1.07	0.45	0.75	0.99	0.42	0.70
1.16	0.49	0.90	1.11	0.47	0.86	1.01	0.43	0.78	0.93	0.39	0.72
1.11	0.47	0.94	1.05	0.44	0.89	0.96	0.41	0.81	0.88	0.37	0.74
1.06	0.45	0.97	1.01	0.43	0.92	0.92	0.39	0.84	0.84	0.35	0.77

MATERIALS FOR ONE CUBIC YARD COMPACT PLASTIC MORTAR BASED ON BARREL OF 3.8 Cu. Ft.

FROM "CONCRETE PLAIN AND REINFORCED"

By Taylor & Thompson

Relative Proportions by Parts		Relative Proportions by Volume		Packed Cement bbl.	Loose Sand cu. yd.
Cement	Sand	Cement bbl.	Sand cu. ft.		
1	0	1		8.31	
1	½	1	1.9	6.73	0.47
1	1	1	3.8	5.01	0.71
1	1½	1	5.7	4.00	0.84
1	2	1	7.6	3.32	0.93
1	2½	1	9.5	2.84	1.00
1	3	1	11.4	2.48	1.05
1	3½	1	13.3	2.20	1.08
1	4	1	15.2	1.98	1.11
1	4½	1	17.1	1.80	1.14
1	5	1	19.0	1.65	1.16
1	5½	1	20.9	1.52	1.18
1	6	1	22.8	1.41	1.19
1	6½	1	24.7	1.32	1.21
1	7	1	26.6	1.23	1.21
1	7½	1	28.5	1.16	1.22
1	8	1	30.4	1.10	1.24

NOTE:—Variation in the fineness of the cement and the sand, and in the consistency of the mortar, may affect the values by 10% in either direction.

Cement—as packed by manufacturer.

Sand—loose.

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